REPORT OF THE WORKING PARTY

ON

SARDINE AND MACKEREL RESOURCES

ICAR

INDIAN COUNCIL OF AGRICULTURAL RESEARCH
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PREFACE

Sardines and mackerels constitute 20 to 30 per cent of the total marine fish catch of India. Their behaviour has intrigued scientists and fisheries development officers, mainly because of the wide yearly fluctuations in the landings. It is suspected that large stocks of these fishes exist in some parts of the Indian Ocean. However there is paucity of knowledge regarding their breeding habits, breeding grounds and migrations.

Considering these groups as extremely important for adding to the fish landings with concomitant possibilities of establishment of industrial complexes based on fish as raw material, a Working Party was constituted in 1966 to collate information relating to fisheries and biology, collect and compile a bibliography relating to sardines and mackerels, prepare maps and charts to indicate the occurrence of these fishes along the Indian coasts, and compile a list of active workers in the line. The Working Party has now prepared a comprehensive report on the available information and has indicated the further line of work to be carried out in this field. It is hoped that this would be a valuable contribution to the development of sardine and mackerel fisheries in India.

NEW DELHI
December 18, 1969

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Joint Commissioner (Fisheries)
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1. INTRODUCTION

In pursuance of the recommendation of the Fisheries Research Committee at its 13th meeting, held at Madras on October 31 and November 1, 1966, the Government of India decided to constitute a Working Party to prepare a report on sardine and mackerel resources in India. The Working Party consisted of the following members:

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The terms of reference of the Working Party were as follows:

1. Collection and compilation of bibliography relating to sardines and mackerel.
2. Collection and compilation of a list of active workers in the respective fields.
3. Collection and compilation of the available information relating to the fisheries and biology of the two groups.
4. Arrangement of meetings and discussions to digest the information already available and preparation of a report on what has been done so far and what is to be done in future.
5. Drawing up 'sardine maps of India' and 'mackerel maps of India', showing location and age composition during the different months of the year, superimposed on maps showing oceanographic features.

The Working Party collected all the available information relating to mackerel, oil-sardine and the lesser sardines of Indian waters which form the basis of the synopsis on the biology and fishery of these fishes. Through the courtesy of the Central Marine Fisheries Research Institute, Mandapam, the Working Party was able to collect data on the hydrographic features, and age and size composition of the commercial landings of sardines and mackerel. Based on these, 'sardine and mackerel maps' have been prepared. The data assembled together have been critically examined and a résumé given of what has been done so far, what is to be done in future, and certain observations on hydrographic factors in relation to oil-sardine and mackerel fisheries.

The Working Party would like to place on record its sincere thanks to the staff of the Central Marine Fisheries Research Institute, Mandapam, who have helped in many ways in the preparation of this Report.

2. SYNOPSIS OF THE BIOLOGY AND FISHERY OF THE INDIAN OIL-SARDINE

Common names: Kannada: *Buthia, Baige*; Malayalam: *Mathi, Nallamathi*; Marathi: *Tarali, Haid*; Tamil: *Nonalai, Paichalai*; Telugu: *Noona-Kavallu.*

BIOLOGY

Distribution

The Indian oil-sardine, *Sardinella longiceps* Cuv. & Val., has a rather limited geographical distribution. The range extends from Arabia to the Philippines through Seychelles, India, Ceylon, Andamans and Malay Archipelago.

Racial Studies

Based on the study of a few morphometric characters of sardines collected from Malabar and South Kanara coasts, Hornell and Nayudu (1923) felt that there are no local races. Devanesan and Chidambaram (1943) compared sardines from Bombay, Karachi, Muscat, Aden, Karwar and Malabar. The Karwar form possessed the longest head, whereas the Aden, Bombay-Karachi, Muscat and Malabar specimens showed decreasing head length. The Karwar sardine also showed the shortest tail, the length increasing in the Aden, Malabar, Bombay-Karachi and Muscat forms, in the order mentioned. In view of these differences, the authors tentatively concluded that more than one race is present in the population, and suggested that Karwar sardine belonged to a distinct race, somewhere between the Malabar and the Bombay-Karachi races, which in turn separate the Muscat race from the Indian west coast races. They inferred that the Aden form, showing the second longest head and tail, might be an outlying race by itself. Devanesan (1943) studied Bombay-Karachi and Malabar sardines and observed that: (*a*) the length of head in total length is about 3·82 and 3·63 of Bombay-Karachi and Malabar sardines respectively; (*b*) the Bombay-Karachi sardine has long tail and 15 to 17 rays in the pectoral fin, whereas the Malabar sardine has only 15 rays; and (*c*) the stomach of the Bombay-Karachi sardine has uniformly sized sand-grains in large quantities, owing to the bottom-feeding habits of the sardine. He favoured the view that the Bombay-Karachi form belonged to a distinct local race. Nair and Chidambaram (1951) suggested further investigation of this aspect, since the existence of distinct races, if proved conclusively, has an important bearing on the investigations relating to the biology and fishery of the oil-sardine.

Food and Feeding Habits

There are diverse views regarding food of oil-sardines. First the sardines were thought to feed on the flocculent muddy scum found at the bottom of the sea. Later work suggested that sardines feed mostly on plankton, and that the flocculent material found in the stomach was only digested diatoms and other planktonic organisms. It also suggested that when surface conditions are unfavourable sardines may resort to bottom feeding. Recent investigations have more or less conclusively shown that oil-sardines are definitely plankton-feeders, phytoplankton forming the chief food of the juvenile and adult forms. Diatom *Fragilaria oceanica* has been suggested to be their favourite food. The abundance of oil-sardines during certain years may be related to the blooming of this diatom.

During spawning, there seems to be a cessation of feeding activity, as active spawners always have empty stomach.

Migrations

Present knowledge of the migration of oil-sardine is extremely meagre. Hornell (1910) noticed shoals arriving along the South Kanara coast earlier than along the Calicut and Cochin coasts. Chidambaram (1950) stated that sardines appear first in the Calicut region and then progressively towards north, and that they begin to disappear in the north first, then near Calicut, and finally in the south. He correlated the sequence of appearance of shoals with the average surface temperature of sea in different months. He observed a correlation between the gradual increase in temperature from south to north and appearance of sardines from the southern to northern regions, and their final disappearance from north to south in the same retrogressive manner. Panikkar (1952) observed that both sardine and mackerel appear earlier in the south and slowly extend northwards, but that their disappearance follows a reverse pattern.

The sardine fishery lasts longer in the southern areas such as Cochin and Alleppey than in the Malabar and South Kanara zones, but commences earlier in South Kanara centres, being followed subsequently by the Malabar area (Balan, unpublished). This early occurrence in the north may be due to geographic proximity of the shoaling grounds of northern areas when compared with the distant southern places such as Cochin and Alleppey. This feature, to a great extent, appears to be supported by the direct migration of the sardine from offshore areas (areas beyond fishing limits) towards the shore. The young recruits after reaching inshore waters continue to get reinforced uninterruptedly, in spite of heavy fishing mortality, till about summer. With the warming up of waters in summer, the fishery abruptly declines or ends earlier in the northern zone (South Kanara and Malabar). But the fishery persists still further in the southern areas (Cochin and Alleppey), usually till the onset of monsoon.

Thus it is reasonable to believe that the shoals migrate *en masse* from offshore to the inshore areas simultaneously all over the sardine centres in the west coast during the fag end of the monsoon. But during the end of the fishery in summer the shoals move back into the offshore waters, gradually vacating from the northern areas earlier and ending with southern centres later every year.

The tag-recovery data obtained from the intensive tagging programme initiated by the Central Marine Fisheries Research Institute, it is hoped, will give reliable information on the migration of this pelagic species.

Availability of planktonic food and factors such as sea transparency, upwelling, predation from enemies, influence of fishing, variations of sea temperature and atmospheric pressure are likely to influence the migration and fluctuations of the sardine fisheries.

Shoaling Behaviour

Broadly there are 2 types of shoals, the surface and the bottom. Under the former 5 types, viz. flipping, pattering, rippling, leaping and luminescent shoals, have been recognized. In the latter group 2 types, viz. bubble-producing and fish-odour-producing shoals, have been recognized. Normally fish of the same size and age groups shoal together.

The predators such as tunas, dolphins and gulls associated with the sardine shoals influence the shoaling; the dolphins particularly scatter the shoals.

Maturity, Reproduction and Larval History

Oil-sardines mature when they are 14-15 cm long. The oil-sardines are unisexual, but instances of hermaphroditism and gonadial abnormalities have been reported. They show secondary sexual characters. The male has visible muscular papilla in the cloaca and the female corresponding membranous structure.

Key to the Stages of Sexual Maturity

Nair (1959) followed the I.C.E.S. scale (of herring), which is given below, for distinguishing male fish from female fish.

Stage I ... Immature. Gonads very small, often hardly recognizable. Eggs invisible to the naked eye; transparent under microscope.

Stage II ... Gonad length slightly more than half the length of the body cavity. Some eggs opaque; just visible to the naked eye.

Stage III ... Gonads about half the length of the body cavity. Eggs opaque.

Stage IV ... Gonads about two-thirds the length of the body cavity.

Stage V ... Mature. Organs filling the body cavity but not discharging.

Stage VI ... Spawning. Organs discharging or about to do so. Large transparent eggs.

Stage VII ... Spent. Organs blood-shot, flaccid. Large residual eggs present.

(Amended Blackburn, 1941)

Fecundity and Spawning

The oil-sardines lay 70,000 to 75,000 eggs. The fecundity is directly proportional to the weight of the ovary, which in turn is generally related to the size of the fish. The left ovary is larger and produces more eggs than the right one.

The spawning season begins by about June and continues till October. Intense spawning generally takes place during August-September. The south-west monsoon influences greatly the entry of spawners into the coastal waters. Consequent on this, the spawning season shifts slightly from year to year, depending upon the onset of the monsoon.

Spawning usually takes place at night. The fish, it is believed, spawn a few nights before and after the new moon. No precise information is available on the spawning grounds, but judging from the relative scarcity of the planktonic eggs in the fishing grounds, it is presumed that the main spawning grounds are beyond the conventional fishing zone.

Eggs

The eggs are pelagic, transparent and perfectly spherical with an average diameter of 1·4 mm. They possess a very wide peri-vitelline space. The yolk is colourless and its segmentation, a characteristic feature of the clupeid eggs, is seen distinctly. It is roughly spherical with an average diameter of 0·85 mm. The eggs generally have only 1 spherical, golden-yellow oil-globule with an average diameter of 0·1 mm. Occasionally 2 and in rare instances 3 oil-globules are found. The embryonic development is very rapid and is usually completed within 24 hours.

Larvae

Newly hatched larvae measure 2·75 mm in average length, and float on the surface owing to the buoyancy of the yolk and the oil-globule. The yolk is ellipsoidal and extends nearly two-fifths the length of the larva. The oil-globule generally occupies a central position near the ventral periphery of the yolk mass. The myotomes are distinct and their muscle fibres show the characteristic crossed arrangement seen in clupeid larvae. Pigmentation is very feeble and is confined to the dorsal side of the larva in the form of scattered, unbranched black pigment cells, arranged closely in the anterior region and sparsely in the posterior region.

One-day-old larvae measure 3·35 mm in average length. There is a considerable reduction in the size of the yolk mass and its segmentation becomes faint. The oil-globule disappears. The auditory vesicle is large. The developing pectoral fin appears as a flap-like structure behind the auditory vesicle. The lower jaw appears as a bud-like projection. The origin of the dorsal fin fold shifts anteriorly opposite to the base of the pectoral fin. The black chromatophores present on the dorsal side are larger and stellate, and have begun to migrate to the ventral side. This migration commences from the posterior end, where a linear group of highly branching black chromatophores is present on the ventral side of the post-anal region. The actual process of vertical orientation of the chromatophores is seen in the middle portion of the larva, where several such pigment cells are present on the lateral sides of the myotomes. The eyes are golden yellow, and a few irregularly arranged yellow pigment cells are present in the caudal region.

Two-day larvae measure 3·7 mm in average length. They are very active, and at the slightest disturbance dart from place to place in a serpentine manner. The yolk is completely absorbed and the mouth is well developed. The auditory vesicles and the pectoral fins have become larger. The alimentary canal shows a slight widening of its posterior half. The basic pigmentation of the larva becomes stabilized and all the pigment cells present on the dorsal side have migrated to the ventral side.

The post-anal pigmentation is very conspicuous owing to the accumulation of highly dendritic black chromatophores. A few large, stellate, black pigment cells are present in the region of the heart. The pigmentation of the alimentary canal is characteristic. The chromatophores are arranged on the dorsal side throughout its entire length, and are confined to the posterior half on the ventral side. The eye colour resembles that of the adult in having a silvery-white colour and shine (Nair, 1960).

The 3-day-old larvae resemble the previous stage, except in the reduction in length.

Age and Growth

Hornell and Nayudu (1923) traced the passage of 3 generations of oil-sardines through the fishery and estimated the growth rate and age by the majority size method and by the growth markings in the form of rings on the scales. They concluded that the oil-sardine attains a size of 15 cm at the age of 1 year. During the second year the growth is extremely slow and the increase is about 1 cm. The oldest sardines examined by them were about 2½ years old.

Devanesan (1943), through growth checks in scales, concluded that oil-sardine has a life-span of about 14 years, and that it attains a size of 6·5, 8·7, 15 and 18 cm at the end of 1, 6, 9 and 14 years respectively.

Nair (1949) studying otoliths found 2, and in exceptional cases 3, growth rings and suggested a life-span of 3 to 4 years. Later, he (1953), using the averages of modes in length-frequency data over 4 years, stated that the oil-sardine attains the size of 10, 15 and 19 cm, respectively, at the end of 1, 2 and 3 years of age, and suggested the possibility of the existence of a 4th year class. Chidambaram (1950) observed that the life-span of oil-sardine is between 3 and 4 years, with average length of 10·0, 14·5, 18·3 and 20·5 cm at the end of first, second, third and fourth years respectively. Balan (under publication), by studying growth checks on scales and back-calculating the length of the fish at the growth-check periods, concluded that the oil-sardine on an average attains the size of 14·3, 16·4 and 18·6 cm at the end of 1, 2 and 3 years of age respectively. He found 3 growth checks in 6 per cent of the material examined and no fourth growth checks.

There is thus divergence of opinion regarding the size the oil-sardine attains at the end of the successive years of its life. The most divergent view is that of Devanesan. He probably confused the circuli as growth rings. Apart from this, there are basically two views. The first held by Hornell and Nayudu assumes that the juveniles found in a season are the products from the same spawning season (not more than 5-6 months old when entering the fishery). The second view held by Chidambaram and Nair implies that they are the products of spawning of the preceding years, i.e. they are more than 1-year old when entering the fishery.

Examination of length-frequency data showed that oil-sardine grows at a very fast rate, of 4 to 5 cm a month, in the early stage of life and that generally a new group with mode at 10-12 cm or so is recruited in the fishery some time in August to October, the growth of which can be traced for subsequent months. In some years, sometimes new recruits with the modes at 6 to 8 cm are seen earlier in June or July. These are considered to be of 0-year class, and the 10-12-cm group entering the fishery in August to October to be of 1-year class. In view of the very fast growth in the early part of life, 6- or 8-cm group seen in June-July are now considered to grow up to 10-12-cm group almost the next month. Hence 10-12-cm group entering the fishery really belongs to 0-year class, as was believed by Hornell and Nayudu. Follow-up of this group indicated that oil-sardine attains sizes of 15·5, 17·5 and 18·5 cm at the end of first, second and third years respectively. This corroborates the findings of recent scale studies by Balan.

The estimates of parameters in Bertallanfy's growth equation have been obtained as k=0·45 and 1 C=21 cm.

FISHERY

Population (Stock)

Sex-ratio: Both the sexes occur more or less in equal numbers up to a size of about 20 cm, thereafter there is a slight preponderance of females in certain regions.

Age/size composition of commercial landings: The commercial fishery begins to exploit the fish from about the size of 10 cm (corresponding to the age of about 3 months), even though a small percentage of fish below 10 cm is also caught. The following Table gives the size and age composition of the commercial catch (in percentage) for the various centres.

	Per cent of fish (numbers) caught				Above
	below 10 cm	10–15 cm	15–17 cm	17–18 cm	18 cm
	(0–year class)				3–year
	below 3 months	3 months to 1 year	1–year class	2–year class	class or above
Mangalore:					
(average of 1958–59 to 1962–63)	0·67	86·10	10·26	2·26	0·71
Cannanore:					
(average of 1951-52 to 1962–63)	6·76	89·68	2·16	0·88	0·52
Calicut:					
(average of 1954–55 to 1962–63)	4·58	67·62	18·28	5·96	3·56

The major portion of the commercial catch comes from the 0-year class, and hence the success of fishing depends on the strength of the incoming 0-year class entering into the fishery.

Mortality: Natural mortality is very high among both the sexes after spawning. An instance of large-scale mortality of oil-sardines, probably caused by foul water along the Malabar coast in November 1908, was reported by Hornell (1910).

Banerji (unpublished) observed that in oil-sardine the total annual instantaneous mortality coefficient is about 1·59, and the component of annual instantaneous natural mortality is 1·47. The author also pointed out that, in view of the short life-span and in consequence of the very high natural mortality rate, the annual fishing success would heavily depend on the numerical strength of the incoming year classes and would, therefore, be relatively unstable.

Competitors and Parasites

The Indian mackerel may be considered as a competitor for food. An inverse relation has been observed in their catches, one becoming less when the other is more.

A tetraphyllid cestode larva *Platybothrium sardinellae* from the pyloric caeca and an advanced larval trematode from the pyloric caeca and stomach are the parasites recorded (Hornell and Nayudu, 1923). The latter parasite is common during the months of January, March and April.

Fishing Season

The oil-sardine fishery, along the west coast of India, commences with the appearance of spawners during the south-west monsoon (by the end of June or early July). During the post-monsoon months the spawners disappear and the juveniles enter and support the fishery during the peak period. The spent oil-sardines again appear towards the closing stages of the fishery. The fishery comes to a close by March-April, the peak period being between August and January, depending on the region.

Fishing Areas

The bulk of the fishery is found along the west coast and generally large-scale shoaling takes place along the Kanara and Malabar coasts. Occasional shoals have been caught as far north as Bombay and Kathiawar. Along the east coast small-scale fishing has been reported from the coasts of Tamil Nadu, Andhra Pradesh and Orissa States.

Catch

Annual fluctuation in oil-sardine fishery is well known. They are " abundant in some years, they occasionally forsake their haunts for several consecutive seasons, returning again in enormous quantities. " This is evident from the fact that the fluctuations have been between 8·8 tonnes in 1946-47 and 3,59,291 tonnes in 1964-65. Landings of oil-sardine from 1925 to 1965 are given in the following Tables.

LANDINGS OF OIL-SARDINE IN SOUTH KANARA AND MALABAR, 1925-50 (NAIR AND CHIDAMBARAM, 1951)

Years	Oil-sardine (tonnes)	Years	Oil-sardine (tonnes)
1925–26	44,507·2	1930–31	4,324·8
1926–27	14,804·5	1931–32	2,185·4
1927–28	7,204·0	1932–33	1,123·9
1928–29	1807·7	1933–34	71,769.5
1929–30	2,753·7	1934–35	20,834·7
1935–36	1,498·5	1943–44	442·5
1936–37	27,161·7	1944–45	656·7
1937–38	17,021·2	1945–46	17·7
1938–39	3,413·2	1946–47	8·8
1939–40	7,090·2	1947–48	1,191·1
1940–41	25,268·8	1948–49	290·7
1941–42	4,450·2	1949–50	3,390·0
1942–43	919.5		

LANDINGS OF OIL-SARDINE IN KERALA AND MYSORE, 1950-65 (FIGURES IN TONNES)*

Seasons	Kerala	Mysore	Total for India
1950–51	12,442	1,643	14,200
1951–52	19,545	1,853	21,419
1952–53	27,664	10,201	40,258
1953–54	19,519	2,762	22,479
1954–55	41,306	6,648	48,955
1955–56	14,196	837	15,033
1956–57	20,175	2,141	32,247
1957–58	243,393	5,746	249,147
1958–59	74,949	542	82,224
1959–60	32,163	2,970	35,345
1960–61	260,508	2,734	263,255
1961–62	91,181	6,006	97,642
1962–63	115,644	10,091	130,922
1963–64	47,241	8,523	57,406
1964–65	281,548	77,742	359,291

* Since the landing figures for 1925 to 1950 were available only for the seasons, the figures for 1950 to 1965 have also been given for the seasons for the sake of comparison.

Craft and Gear

The types of fishing gear and craft used for sardine fishing in India are described in the Table below.

Fishing area	Type of boat	Type of net	Vernacular name
Konkan	*Doni* with outrigger	Shore seine	*Rampani.*
	Mechanized boat	Purse seine	—
Kanara	*Doni* with outrigger	Shore seine	*Rampani.*
		Gill net	*Idabale.*
		Cast net	*Veechubale.*
Kerala	Dugout canoe	Boat seine	*Mathikolli vala, Pattumkolli vala, Arakolli vala, Paithuvala/Odam vala/peruvala, Thattum vala, Nethal vala, Nona vala, Thangu vala.*
		Shore seine	*Karavala.*
		Encircling gill net	*Mathichala vala.*
		Cast net	*Veechu vala.*
	Mechanized boat	Purse seine	—
Tamil Nadu ...	Catamaran	Gill net	*Kolavala, Chala vala.*
	Masula-type boat (*Padagu*)	Cast net Shore seine	*Veechu vala,* *Peria vala* or *Karavala*
Andhra Pradesh ...	Catamaran	Gill net	*Katla vala*
	Masula boat	Shore seine	*Pedda vala.*

Gear Efficiency

No systematic study has been made to find out the efficiencies of different gears. Such a study will require comparison of performances of various gears operated at

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common places and times. The Table below shows the catch obtained by different gears per unit effort in Calicut waters from 1955-56 to 1958-59.

Gear	Catch per unit operation* (kg)				Relative efficiency				
	1955-56	1956-57	1957-58	1958-59	1955-56	1956-57	1957-58	1958-59	Average
Mathikolli vala ...	3·60	3·41	10·11	13·17	1·00	1·00	1·00	1·00	1·00
Pattumkolli vala ...	—	1·58	4·92	10·47	—	0·46	0·49	0·79	0·58
Arakolli vala ...	2·26	0·52	—	—	0·63	0·15	—	—	0·39
Mathichala vala ...	0·92	1·00	4·87	3·27	0·25	0·29	0·48	0·25	0·32
Paithuvala ...	0·05—	0·02	7·11	1·26	0·01	0·01	0·70	0·10	0·20
Thattum vala ...	0·65	1·43	7·88	1·35	0·18	0·42	0·78	0·10	0·37
Arathattum vala ...	1·80	0·52	—	—	0·50	0·15	—	—	0·33
Nethal vala ...	0·33	—	1·49	—	0·09	—	0·15	—	0·12
Veechu vala ...	3·51	1·93	7·18	—	0·97	0·57	0·71	—	0·75
Odam vala ...	—	—	2·29	—	—	—	0·23	—	0·23

* From Sekharan (1962).

The catch per unit effort of various gear varies from year to year due to variation in abundance of oil-sardine. Taking *mathikolli vala's* efficiency as 1·00, the relative efficiencies of other gears are shown in the Table for each year, as also the average efficiency for the 4-year period from 1955-56 to 1958-59. There is considerable intra-seasonal variation in the relative efficiencies of different gears.

Fisheries Management and Regulations

There was unprecedented failure of the oil-sardine fishery over a number of years during the forties. This had disastrous effects on industries based on it. The erstwhile Government of Madras took note of the situation and introduced restrictive legislation to prevent the capture of the juveniles and spawners in 1943. The main clauses were the prohibition of:

(*a*) the use of the highly destructive boat seine, *mathikolli vala*, during the sardine season from August to April;

(*b*) the use of the encircling gill net, *mathichala vala*, during the spawning period in August and September; and

(*c*) the landing of more than a total weight of 37 kg (1 maund) of oil-sardine below 15 cm from any single boat during the fishing season.

The legislation was modified in 1945 and extended for 2 more years to prohibit the use of these nets throughout the season and the landing of immature sardines. This legislation, which lapsed in 1947, was not extended any further owing to the practical difficulties encountered in its enforcement, the lack of preventive staff over a long coast-line and of similar legislation in adjacent States.

Factors Responsible for the Fluctuation in the Fishery

Day, a little over a century ago, in his book *The Fishes of Malabar*, wrote: " it must be left for future years to demonstrate whether the present increase of the fish-oil trade is a healthy or unhealthy stimulus due to the present high prices; for if the latter, the fisheries are being overworked and the future loss will be great. The extreme violence of the south-west monsoon of course protects the fish from the commencement of June until September, but the period of the year at which the various species spawn, more extended observation on their arrival and departure and a thorough examination into the fish that is captured as to whether the young are or not used for salting or fish-oil, are objects which it would be very importane to ascertain." Later, Hornell (1910) suggested the necessity for a sound knowledge of the factors controlling and influencing migrations. He further suggested that the disappearance of sardine shoals in consecutive years may be due to a combination of unfavourable conditions in the inshore waters, resulting in the low production of diatoms which normally attract the shoals. Sundara Raj (1934 a, b, 1937) thought that the capture of larger numbers of immature sardines is likely to affect the fishery adversely. Devanesan (1943) suggested overfishing, and Devanesan and Chidambaram (1948) instrusion of an immature generation in the fishery as the probable causes of fluctuation. Chidambaram (1950) stated that temperature, salinity and the availability of food control the spawning and survival of larvae and fry. Nair (1953) concluded, on the basis of his study on their food and feeding habits, that the availability of *Fragilaria oceanica* is one of the major factors governing the fluctuations. According to him the optimum temperature, salinity and the availability of *Fragilaria* are the factors influencing the movements of juveniles, the abundance of which is the deciding factor in the success or the failure of the fishery.

Murty and Edelman (under publication) correlated the long-term fluctuations of the Indian oil-sardine fishery with the strength of the summer monsoon. The difference in sea-level pressure between Cochin and Bombay, as an expression of monsoon intensity in that region of the Arabian Sea (adjacent to the west coast of India), revealed good correlation with the sardine fishery of that region. Certain ranges of monsoon intensities were unfavourable for the fishery and certain others favourable. The unfavourable range is of low intensities during which the pelagic waters are depleted with dissolved oxygen due to upwelling phenomenon. The favourable range is of higher intensities during which the wind-mixing could compensate for the loss of oxygen caused by upwelling.

RESUME OF WORK DONE AND FUTURE LINE OF WORK

Fish

At present some knowledge about the distribution of the juvenile and adult fish is available. Where the fish disappear after leaving the fishing grounds and whether there is a demersal phase in its life-history are not known as yet. Very little is known about distribution of larvae and eggs.

The fish grows at a very rapid rate in the initial stages of its life; thereafter the growth slows down considerably. Recent studies on length-frequency distribution and scale readings indicate that the fish attains a size of 15 cm at the end of the 1st year, 17 cm at the end of the 2nd year, and 18 cm at the end of the 3rd year of its life.

The fish matures when about 14-15 cm long, i.e. at about 1 year of age. It is a prolific breeder producing on an average 70-75 thousand eggs. The frequency of spawning in a season or in the entire life-span of the fish has yet to be determined. The spawning season is sometimes from May to September. The spawning grounds have not yet been discovered but are believed to be located beyond the limits of traditional fishing grounds.

Considerable work has been done on food and feeding habits of oil-sardine. The constituents of food are known. The fish is mainly a phytoplankton feeder.

Some broad characteristics regarding the behaviour of the fish are known. An annual shoreward migration of the bigger fish first, followed by the juveniles is an important feature. The cause of this migration has not been definitely established. This shoreward migration takes place after the commencement of the south-west monsoon. The fish moves away from the inshore fishing grounds by about March and April. The fish moves in schools of various sizes in the fishing grounds, but such schools have not been found outside the limits of fishing grounds. The fish in a single school are generally of the same size.

Fishery

The present distribution in space and time of the commercial fishery is well known. It is, however, not known definitely if the commercial fishery depends on one population or on more than one subgroup of the same population. This aspect requires statistical analysis of morphometric data, serological studies on samples obtained from various places, and extensive tagging experiments.

Major portion of the commercial catch is formed by the 0-year class. The fishing success in a year depends mainly on the strength of the incoming 0-year class that is recruited to the commercial fishery. This variation in the abundance of the 0-year class recruits and therefore the variation in the magnitude of catch may result either from the fishing activity or from other fishery-independent factors. If fishing is actually responsible for the fluctuation, then there is decreasing catch per unit effort with increasing input of effort. However such relations have not been found, indicating that fluctuations in the 0-year class recruits and therefore in the catches must be occurring due to some fishery-independent environmental factors. This is further supported by the fact that the component of instantaneous mortality rate is a negligible part of the total instantaneous mortality rate. The estimate of total instantaneous mortality is 1·59, whereas the estimate of instantaneous fishing mortality exerts very little influence, either on the newly recruited class or on the spawning stock.

The environmental factors may affect the stock in 2 ways, viz. they may affect the availability of the fish in the fishing grounds, or the survival of young sardines from any season's spawning and thereby affect the recruitment class. Prior to 1957-58 fishing season, both the catch and the relative abundance of sardines in the fishing grounds were low, but showed very substantial increase thereafter. Obviously some environmental changes took place during this time, which made more fish available for exploitation and also probably determined successful survival of young sardines to be recruited to the fishery in large numbers. It is thus necessary to study and make a critical analytical study of the oceanographic data for the two periods prior to and after 1957-58. As adequate oceanographic data prior to 1957-58 are not available, meteorological data for these two periods may have to be used to understand what exactly happened in 1957-58, which caused a sudden increase in the abundance of sardines. Murty and Edelman (unpublished) correlated the long-term fluctuations of the oil-sardine fishery with the strength of the summer monsoon. The difference in sea-level pressures at Cochin and Bombay, as an expression of monsoon intensity in that region, revealed good correlation with the oil-sardine fishery. Thus a prediction based on the analytical study of meteorological data may permit the future prediction of oil-sardine fishery. More studies in this direction are indicated.

The oceanographic data collected after 1957 are being analysed and correlated with annual abundances of sardine with a view to identifying the environmental factor or factors responsible for fluctuations in fisheries. As a preliminary step, the averages of certain oceanographical characteristics like salinity, temperature, oxygen content, density, etc. were calculated for each one degree square and plotted on a map month by month. The data on average abundance of fish in different months were also superimposed on the maps. The trend of changes in the oceanographic parameters was correlated with that of changes in the abundance of the fish. Although some general relations were noticed, no clear picture of correlation emerged from such a study. Probably, the averages over years might have smoothed out any anomalies in these parameters, which could have explained the influence of environments on the abundance of fish. Such correlation studies on the basis of yearly data rather than those on the basis of average data over several years are indicated. As surface data are liable to be affected by local influences, subsurface data (10-20 m) will have to be utilized for any such studies.

RECOMMENDATIONS

The above review points out that it is high time that an extensive survey of the offshore areas is made and the nursery and spawning grounds found out. The measures of relative abundance of different year classes in the catch must continue. The same work has got to be extended to spawning and nursery grounds when they are found out. Collection of chemical and physical data on a more intensive scale must be continued both in the fishing grounds and offshore grounds and satisfactory methods of analysis developed. Analysis of abundance of various year class of the commercial catch must also continue to see if any changes in the natural and fishing mortalities are taking place. Increased use of mechanized methods for more efficient exploitation and exploration is recommended.

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3. SYNOPSIS OF THE BIOLOGY AND FISHERY OF THE INDIAN MACKEREL

Common names: Kannada: *Bangada*; Marathi: *Bangada*; Malayalam: *Ayala*; Sindhi: *Oibia gedar*; Tamil: *Ailai, Kumla, Kanangeluthi*; Telugu: *Kanagurta, Kamangadachalu, Kannangadatha, Vahjiramu.*

BIOLOGY

Distribution

The Indian mackerel, *Rastrelliger kanagurta* (Cuvier), has a wide distribution in the tropical Indo-Pacific. It has been recorded in the Indian Ocean from the Persian Gulf, Somalia, Seychelles Islands, Mozambique in Delagoa Bay, coast of South Africa around Durban, Pakistan, coasts of India, Andaman and Nicobar Islands, Ceylon and Burma. In the central Indo-Pacific it has been recorded from Malaysia, Thailand, Cambodia, Philippines, Indonesia, Australia along the coast of Queensland, New Guinea, Melanesia, Micronesia and Polynesia areas, islands of Bouganiville, Solomon, New Hebrides, Fiji, Samoa, coast of Peoples Republic of China, Taiwan, Hong Kong, Tyuku and Hawiian Islands.

In addition to *Rastrelliger kanagurta* at least one more species, *R. brachysoma*, is known to constitute the fishery in certain regions of the Indian ocean and central Indo-Pacific. The distribution of this species seems to be restricted to the waters of South Africa around Durban, Andaman Islands, Malaysia, Thailand, Philippines, Indonesia, New Guinea, Fiji and Solomon Islands.

Racial Studies

Racial studies on *Rastrelliger* have been attempted in the Philippines and India but have not resulted in any tangible conclusions.

Food and Feeding Habits

Mackerel feeds mainly on phyto- and zooplanktons. The common phytoplankton fed upon are *Coscinodiscus, Dinophysis, Peridinium, Pleurosigma, Chaetoceros* sp., *Fragilaria oceanica, Thalassiothrix frauenfeldi, Nitzschia seriata, Skeletonema costatum* and *Thalassionema*. The common zooplankton that form the food are tintinnids, *Evadne, Penilia*, Cypris larvae, copepods like *Oithona* sp., *Acrocalanus* spp., *Temora turbinata, Schmackeria serricaudata, Euterpina acutifrons, Labidocera, Acartia, Eucalanus* and *Squilla* larvae, *Alima* larvae, gastropod larvae, bivalve larvae and fish post-larvae.

The type of food eaten varies in different regions.

1959-60 Season: At Mangalore the main items observed in the stomach contents were copepods, cladocerans and larval bivalves among zooplankton, and *Coscinodiscus* among phytoplankton. At Calicut the stomachs (204-231 mm) of fish were full, mainly of copepods. Phytoplankton contributed only a minor portion of food, chiefly by species of *Dinophysis, Coscinodiscus, Peridinium* and *Pleurosigma*. Large number of tintinnids were also seen. Other food items were crustacean eggs and larvae, bivalve larvae and cladocerans. At Vizhingam mackerel fed exclusively on planktonic organisms. In the first and the last quarters zooplanktonic forms like copepods, *Squilla* larvae, prawn larvae, pelecypod larvae and *Acetas* sp. formed important constituents. In the second and the third quarters the phytoplanktonic fraction constituted the major item of their food.

1960-61 Season: During June to August the stomach contents of fish at Karwar had diatoms. *Chaetoceros* sp., *Fragilaria oceanica*, *Thalassiothrix frauenfeldi* and *Nitzschia seriata* were found abundantly. Samples from offshore collections had dinoflagellates and many zooplankton elements. At Mangalore phytoplankton was dominant from April to August, and zooplankton (*Evadne*, *Penilia* and copepods) from August to March. At Cannanore mackerel was found to feed on planktonic organisms, with two peak periods of feeding, one in September-November and the other in January-March. Generally phytoplankton dominated over zooplankton, although the latter was dominant in certain months. At Ernakulam active feeding was observed from October to March with the predominance of copepods. A variety of diatoms and dinophysids were also met with. In June juvenile mackerel (150-160 mm) fed exclusively on fish post-larvae. At Vizhingam both phyto- and zooplankton were noticed in gut contents. *Phyllosoma*, *Alima* and cypris larvae, copepods, crustacean remains, bivalve and gastropod larvae, and the diatoms *Skeletonema costatum* and *Nitzschia* were observed. At Porto-Novo feeding was intense and indiscriminate throughout the season and during day as well as night. Gut contents largely reflected the composition of inshore plankton and its fluctuations.

1961-62 Season: At Karwar intensive feeding was observed in April. During April to August phytoplanktonic elements were prominent. Dinoflagellates, cladocerans and copepods like *Oithona* spp., *Acrocalanus* spp., *Temora turbinata*, *Schmackeria* and *Euterpina acutifrons* formed the main food during the post-monsoon months. At Mangalore in October, cladocerans *Evadne tergestina* and *Penilia avirostris* were dominant. Copepods were dominant in other months. At Cannanore the phyto- and zooplanktons formed the main food. At Calicut copepods formed the main food throughout the year. *Labidocera*, *Acartia* and *Temora* formed the major part of food in the early half of the year, and *Temora*, *Labidocera* and *Eucalanus* in the latter half. Other items were *Evadne*, *Penilia*, crustacean eggs, *Lucifer*, tintinnids, bivalve larvae, and the diatoms *Pleurosigma* and *Coscinodiscus*. The food consisted of copepods, other crustaceans, *Alima*, cypris larvae, *Skeletonema costatum*, *Thalassiothrix*, *Nitzschia* and *Thalassionema* at Vizhingam. Examination of stomach contents of mackerel from trawl catches at Bombay showed the presence of forminiferan shells and sand grains.

Gut contents largely reflected the composition of the inshore plankton, and its fluctuation from season to season and from place to place. Mackerel do not show any specific preference to either phytoplankton or zooplankton, nor are they carnivorous and cannibalic. However, they are reported to discriminate the edible food from the non-edible food (Noctiluca, medusae, chaetognatha, etc.). The food of young and adults does not differ radically. Feeding increases as the fish grows and advances in maturity and decreases as breeding commences, but increases again at the end of it. Feeding in both the sexes is almost the same. Mackerel shows feeding migrations, especially to places where plenty of plankton is available. They are filter-feeders feeding mainly at the surface.

Migrations and Shoaling Behaviour

Mackerel are pelagic fish occurring in shoals, which are visible from a distance as dark patches with ripples during day and as phosphorescent patches during night. Shoals move in semi-circular or arrow-head formations, and usually along the current of water at high tides. They enter inshore waters with north-easterly winds. According to Pradhan (1956) in Karwar, shoals enter inshore waters with north-easterly winds. When there is strong easterly winds, mackerel shoals come close to the shore through deeper layers of waters. The shoals disappear down quickly as the boats approach them. When attacked by seer fish they scatter. When chased by sharks, they submerge with head downwards in a compact mass. When attacked by porpoise they dive and scatter.

Mackerel shoals move at a speed of about 8 to 10 nautical miles per hour (Pradhan, 1956). Subsequent observations carried out by the Central Institute of Fisheries Technology indicate that the normal swimming speed is only 3 to 4 knots.

Maturity, Reproduction and Larval History

The minimum size at maturity varies from 20 to 22·4 cm. Sex can be differentiated when the fish is about 12 cm in length. There are instances of hermaphroditism. There are no secondary sexual characters.

Key to the Stages of Sexual Maturity

A key to the stages of sexual maturity of the gonads of females and males (Pradhan and Palekar, 1956) is shown in the Table on the next page.

Fecundity and Spawning

Rastrelliger kanagurta lays on an averge 94,000 ova. The spawning season is a prolonged one, beginning by about April and lasting till September. Off Vizhingam possibly there are 2 spawning periods, viz. May-August and November-March. Similarly, off Mandapam 2 distinct spawning seasons, viz. October-November and May-June, have been observed. Further north along the east coast the breeding season is during or after the north-east monsoon.

The ova are released in batches and it is believed to spawn in succession over a prolonged period. Only a small percentage of ova mature each time, giving the ovary a speckled appearance described as 'plum-pudding' stage. The number of batches released in a spawning season is not known and consequently the number of eggs spawned during the season is difficult to determine.

Very little information is available on the spawning grounds. Mackerel spawn in slightly deeper waters outside the usual range of our fishermen, but not far

Extent of ovary/testis in the body cavity	Range	State of maturity	Maturity stage
	Ovary		
Less than half the length of the body cavity.	0·038–0·13 0· 14–0·27	Im	I
Slightly more than half the length of the body cavity.	0· 28–0·37	m	II
Extending to about 2/3rd the length of the body cavity.	0· 37–0·46	m	III
Extending a little over 2/3rd the length of the body cavity.	0· 46–0·56	m	IV
Extending over the entire length of the body cavity.	0· 57–0·81	M	V
Extending over the entire length of the body cavity.	0· 57–0·81 0· 57–0·81	M M	VI(a) VI(b)
Shrunken ovary about 1/2 the length of abdominal cavity.	...	S	VII
	Testes		
Less than 1/2 the length of the body cavity.	...	Im	I
Slightly more than 1/2 the length of the body cavity.	...	m	II
Extending to about 2/3rd the length of the body cavity.	...	m	III
More than 2/3rd the length of the body cavity.	...	m	IV
Extending over the entire length of the body cavity.	...	M	V
Extending over the entire length of the body cavity.	...	M	VI
Comparatively much reduced in size	...	S	VII

* Im: immature; m: maturing; M: mature; S: spent fish.

off from the coast. There appears to be good spawning grounds of this fish off Vizhingam and Madras.

Observations made at Porto-Novo suggested that the spawning takes place at night.

Eggs

Information available on the eggs and their distribution is very fragmentary and hardly confirmatory. The mature ovum is transparent, measuring 0·88-0·90 mm in diameter and usually has a large oil-globule of 0·23 mm diameter. Sometimes 3 to 4 oil-globulets are present. The eggs are believed to be pelagic. Nothing is known about the development.

Larvae and Juveniles

No information is available on the early stages. They may also be pelagic. Peter (1967) recently reported the occurrence of early larvae in the Arabian Sea and the Bay of Bengal.

Post-larvae of 5 to 6 mm are reported from plankton off Madras. Balakrishnan (1957) reported that pre-larvae, measuring 2·8 and 5 mm, occur in the plankton off Vizhingam, but does not give the actual description or any figure of the larvae. Gorbunova (1963, 1966) reported the occurrence of larvae and post-larvae from the Indian Ocean.

Small juveniles of *R. kanagurta* occur periodically in the inshore waters and are reported from several places off the coast of Arabian Sea, the Bay of Bengal and the Andaman Sea. Hitherto they were caught in shore-seines along with other fishes. Often commercial catches are constituted by juveniles only.

Age and Growth

Pradhan (1956) discussed the length-frequency data relating to the years 1948-49 to 1952-53. He remarked that the Indian mackerel, at Karwar, ranging from 6 to 11 cm with an average size of 10 cm and occurring between July and September, are presumably the offspring of fish which spawned in the previous season, the spawning period according to him being from June to September. He also observed that this group suddenly disappears from the inshore waters after September and a new group of 2 years of age with mode at 18 cm replaces it. He has neither given any justification for his presumption that 10 cm group is 1-year old, nor has he explained why one group should disappear and another older group takes over its place.

Sekharan (1958) analysing the length-frequency data for 1935-36 to 1940-41, taken from Madras Fisheries Department Administrative Reports, concluded that mackerel of 12-16 cm size are of 1 year of age and those of 21-23 cm size of 2 years of age. He traced the mode varying between 12 and 16 cm in July-September for the subsequent months. The mean age of this group, he assumed to be 1 year. His argument was that young mackerel with mode at 6 cm, noticed in June 1940 only, must be of 0-year class, and therefore 12-16 cm group found in July-September in other years must be of 1-year class. He also propounded the hypothesis that very rapid growth takes place during June-September period. An examination of the data shows that while it is true that there is very rapid growth during June-September period, this is with reference to juvenile mackerel only, such rapid growth not being discernible with regard to adult mackerel, i.e. mackerel of size 22 cm and more. Even though rapid growth rate of 7-8 cm in 3 months has been recognized by him with regard to juvenile mackerel, obviously similar rapid growth, if not more rapid rate of growth, must have taken place before 12-16 cm group entered the fishery in July-September period. Hence his conclusion that 6 cm group found in June 1940 and 12-16 cm group found in July-September period in other years belong to 2 different year classes seems to be inconsistent. In fact, Rao (1964) showed very rapid growth in respect of juvenile mackerel examined by him at Waltair in 1954-55. He does not agree with the conclusions of Sekharan and Pradhan regarding the size of mackerel at 1 year of age, and remarks that future studies may show that mackerel of 10-14 cm group actually belong to the 0-year class. Seshappa (1958) found that rings were completely absent in the scales of mackerel in all individuals below 22 cm. Only individuals above 22 cm showed one ring. Probably believing these individuals to be 2-year old after Sekharan (1958) and Pradhan (1956), he explained the 1 ring found as spawning-ring and not age-ring.

A re-examination of all length data collected at different centres of Central Marine Fisheries Research Institute (unpublished) revealed that mackerel has a very rapid growth during the early part of its life and that it has a relatively short span of life. It attains about a length of 22 cm at the end of 1st year and about 24 cm at the end of 2nd year. This interpretation explains why Seshappa (1958) did not find rings in individuals below 22 cm. The mackerel attains a size of 18 cm in about 5-6 months of its life.

FISHERY

Population (Stock)

Sex ratio: In general the 50 : 50 ratio is observed in the commercial catches. This indicates that there is no segregation of the sexes.

Age/size composition of commercial landings: The commercial fishery begins to exploit mackerel from about a size of 18 cm, which corresponds to about 6 months of age. Fish below this size are also caught in good numbers in some places. The following Table summarizes the percentage of fish of different sizes caught at various places.

Place	10–18 cm (up to 6 months)	18–22 cm (6 months to 1 year)	22–24 cm (1 year to 2 years)	24-26 cm (above 2 years)
Karwar: (Average of 1948–49 to 1962–63) ...	5·87	76·62	15·76	1·75
Mangalore: (Average of 1958–59 to 1962–63) ...	36·42	48·96	13·33	1·29
Cannanore: (Average of 1960–61 to 1962–63) ...	55·66	37·09	7·22	0·03
Calicut: (Average of 1957–58 to 1962–63) ...	29·73	63·73	6·45	0·09

The season in Karwar starts 2-3 months later than in the South, and this may explain the low percentage of 10-18-cm group in the catch. Commercial fishery depends mainly on the 0-year class for success.

Mortality: In spite of variations in the levels of abundance of mackerel from year to year, the instantaneous rate of decrease remains constant (Banerji, 1967). Since the mackerel fishery depends mainly on one age group, this furnishes an estimate of instantaneous total mortality, the best estimate of which was found to be 0·64 on a monthly basis. Fishing mortality is relatively a small fraction of the total mortality. As such the mackerel fishery depends mainly on the numerical strength of the incoming age group and is therefore highly unstable from year to year.

Efficiency of exploitation: Banerji and Chakraborty (1962) defined the ratio of unweighted index of abundance to the weighted index of abundance to be a measure of fishing efficiency and showed that the regression coefficient of unweighted index to the weighted index provides the best estimate of fishing efficiency. By using catch per unit effort data obtained at Karwar from 1948-49 to 1958-59, they observed that the fishing efficiency was not significantly different from 1, indicating that the fishing efficiency was not significantly better than what would have been in the case of random fishing. The authors attributed this inefficiency to inadequacy of transport, marketing facilities and other economic factors, rather than to the inability of the fishermen to detect the periods of high abundance and exploit them at that time or due to some other reasons.

Competitors, Predators and Parasites

The oil-sardine on the west coast of India may be considered as a competitor for food. An inverse relation has been observed in their catches, one becoming less when the other is more. Sharks, seer-fish, ribbon-fishes and porpoises are the predators of mackerel. Trematode, cestode and copepod parasites have been recorded from the Indian mackerel.

Fishing Season

The season starts much early in the south zone (Ponnani-Cape Comorin) in August, and lasts till February. In the middle zone (Mangalore-Ponnani) the season commences in August-September and lasts till March-April. In the north zone (Ratnagiri-Mangalore) the duration of the fishery is short, commencing by about October-November and lasting till February-March.

Throughout the west coast the peak period appears to be in November-December. In Karwar and South Kanara two peaks are noticed, one at the beginning and the other at the end of the season. In the Mandapam area the season is from December to March and the best catches are obtained in January-February.

Fishing Area

The main fishery is confined to the west coast of India from Ratnagiri to Cape Comorin. Shoals appear sporadically in the east coast near Mandapam, Nagapattinam, Madras, Kakinada, Visakhapatnam and some parts of Orissa State. The fishery at present is confined to the foreshore and inshore areas only. Although considered as a typical pelagic fishery, there are instances where Indian mackerel occurred in small numbers in the trawl catches taken from Bombay and Saurashtra coasts as well as from the deeper regions (38-73 m) of the Bay of Bengal.

Depending on the intensity of the fishery, the Ratnagiri-Cape Comorin region can be differentiated into 3 zones, viz. (i) Ratnagiri to Mangalore where the fishery is very high, (ii) Mangalore to Ponnani where the fishery is pretty high, and (iii) Ponnani to Cape Comorin where it is poor or moderate.

Catch

Mackerel forms one of our commercially important pelagic fisheries. It forms about 9·5 per cent of the total marine fish produce.

The average catch for 1950 to 1965 (16 years) is estimated to be 63,878 tonnes. The fishery is a highly fluctuating one, the minimum during the period being 16,426 tonnes in 1956 and the maximum 133,655 tonnes in 1960.

TOTAL ANNUAL YIELD OF MACKEREL IN INDIA DURING THE YEARS 1950-1965

Year	Catch (tonnes)
1950	89,163
1951	103,900
1952	78,014
1953	70,754
1954	28,258
1955	22,795
1956	16,426
1957	89,006
1958	123,282
1959	62,198
1960	133,655
1961	34,485
1962	29,103
1963	76,980*
1964	23,863*
1965	43,095†

* Exclusive of Goa; † Inclusive of Goa.

Craft and Gear

Various types of crafts and gears are used in catching mackerel. The more important ones are given below.

TYPES OF FISHING GEARS AND CRAFTS IN INDIA

Fishing area	Type of boat	Type of net	Vernacular name of net
Konkan	*Pandi*, *Hode*; both are provided with outrigger	Shore seine	*Rampan.*
		Gill net	*Pettle bale.*
		Cast net	*Pag.*
	Mechanized boat	Purse seine	—
North Kanara	*Pandi*, *Doni*; similar to above with outrigger	Shore seine	(i) *Rampan.* (ii) *Yendi* or *Payawada.*
		Gill net	*Patta bale.*
		Cast net	*Pag.*
South Kanara	*Pandi* (with outrigger)	Shore seine	*Rampan.*
		Gill net	*Patta bale.*
		Cast net	*Deb balai.*
Kerala	Dugout canoes	Seine net	(i) *Odam vala*, *Peru vala* and *Paithu vala.* (ii) *Ayala kolli vala.* (iii) *Thanguvala*, *Nona/Koruvala.*
		Shore seine	*Kara vala.*
		Encircling gill net	*Ayala chala vala.*
	Mechanized boat	Purse seine	—
Madras	*Masula* boat, Tuticorin type boat	Shore seine	*Periavalai*, *Karavalai* *Thuri valai.*
	Muthupet type canoe, Plank-built boat, Catamaran	Bag net	*Valavalai*, *Kavala valai*, *Koivalai.*
		Gill net	*Madi valai*, *Eda valai.*
Andhra Pradesh	*Masula* boat, Plank-built boat, Catamaran	Shore seine	*Pedda vala*, *Iyal vala.*
		Boat seine	*Iragu vala.*
		Gill net	*Kili vala*, *Silku vala*, *Kavala vala.*
Orissa	*Masula* boat, Plank-built boat, Catamaran	Shore seine	*Pedda vala.*
		Boat seine	*Iragu vala.*

Factors Responsible for Fluctuation in the Fishery

Increase in temperature and salinity adversely affects the mackerel catches, whereas their low values exert a less pronounced effect. Mackerel are more susceptible to changes in temperature than in salinity and the tolerance range of these factors depends on the size of the fish. Large fish (19-21 cm) tolerate increase in temperature and salinity. Smaller fish usually occur in large numbers when low levels of temperature and salinity prevail. One of the criteria for a good mackerel fishery is the degree of variation of temperature and salinity, which should be within the tolerance range. High pH may have an added adverse effect on the fishery. Landings and the total rainfall of an area show an inverse relationship. The wind force cannot be considered as a decisive factor, but it does indicate, in a general way, the trend of the fishery in correspondence with the wind force. The most successful fishery coincided with the period when the wind force was nearest to the mean values.

Mackerel can withstand low salinities even down to 2·04 per cent. They are known to enter estuarine waters of Kali River, Netravaty estuary and Cochin backwaters.

A RESUME OF WORK DONE AND FUTURE LINE OF WORK

Fish

The general nature of the distribution of the fish is known, but very little is known about its habitat after migration away from the fishing grounds. Knowledge about the distribution of eggs, larvae and post-larval forms is scanty. It is necessary to conduct more work to fill up this gap.

The fish has a short span of life. In initial stages it grows very rapidly, attaining a size of about 18 cm within 6 months and 21-22 cm at the end of the first year. Then the growth slows down considerably, probably attaining a size of 24 cm at the end of the 2nd year. The fish becomes mature when about 21 cm, i.e. when about 1-year old.

Spawning takes place almost throughout the year extending from February to November, but no definite evidences are available to show that in a given year the spawning season is protracted over such a long period. This aspect requires careful study. The frequency of spawning of a single individual in a given season or in its entire life-span is not known. This requires further work.

Considerable work has been done on food and feeding habits of mackerel, and the constituents of food are known.

The fish is migratory in habit and moves in schools in the fishing grounds. An annual shoreward migration takes place from July-August onwards and by March-April the fish moves away from the fishing grounds. The causes and factors influencing such migrations are not known and have to be studied.

Fishery

The distribution of the fishery in space and time is generally known. At present, it is believed that the fishery in the west coast depends on only one population. The small fishery in the east coast probably thrives on a different population. This problem needs further study. Statistical analysis of morphometric data, serological studies on samples from various places as well as extensive tagging are necessary for finding out if more than one population forms our fishery.

The commercial fishery begins to exploit the fish from about 18 cm size, even though fish below 18 cm are caught in some quantities in the catch. An analysis of the age and size composition of the catch indicates that the 0-year class forms the major portion of the catch. An analysis of catch and effort data indicates that the fishing success mainly depends on the strength of the incoming 0-year class entering the commercial fishery. The variation in the abundance of the 0-year class in different years may be due to the fishing activity affecting the spawning stock or to other fishery-independent factors. The total instantaneous mortality is very high and instantaneous fishing mortality is very low. This shows that fishing effort does not influence the fluctuations of either the spawners or the new recruit class. This is corroborated by still another study. If fishing is actually responsible for the fluctuation, then with increasing input of effort there will be decreasing catch per unit effort. But no such relations have been found. Such fluctuations must be occurring due to some fishery-independent environmental factors.

The environmental factors may affect the general availability of the fish in the fishing grounds, or they may affect spawning and the subsequent survival of the larval fish, thereby causing fluctuations in the recruitment class. It is thus necessary to collect environmental data both in the fishing and the spawning grounds and correlate them with abundance of mackerel to identify the factor or factors which directly influence(s) the abundance or availability. As a preliminary step, the averages of certain oceanographical characteristics like salinity, temperature, oxygen content and density were calculated for each 1 degree square and plotted in a map month by month. The data on average abundance of fish in different months were also superimposed in the maps. The trend of changes in the oceanographic parameters was correlated with that of changes in abundance of the fish. Although some general relations were noticed no clear picture of correlation emerged from such a study. Probably, the averages over years might have smoothened out any anomalies in these parameters which could have explained the influence of environments on the abundance of the fish. Such correlation studies on the basis of yearly data rather than those on the basis of average data over several years are indicated. As surface data are liable to be affected by local influences subsurface (10-20 m) data will have to be utilized for any such studies.

The mackerel is a short-lived fish. The fishery begins to exploit the fish when it is about 18 cm, i.e. from about 6 months of age. Very few fish above 24 cm size (2-year old) are available to the fishery. Under the circumstances, the time of spawning has an important bearing on the fishing success in the same year. Thus, if the spawning takes place early in a year, in view of very rapid growth in the early part of its life, the fish grow to commercially exploitable size by the time the fishery starts and fishery is likely to be successful. On the other hand, if the major spawning takes place late, say in July-September, the spawned fish will grow to the commercially exploitable size at a time when the fishing season is over and their contribution to the fishery will be very little in the same season and also very little next year in view of high mortality rate. A regular and systematic examination of the gonad condition of even a few specimens above the maturity size of 22 cm every month will greatly help in predicting the success of the fishery in the ensuing fishing season. Attempts should also be made to collect direct evidences of spawning like collection of post-larval forms. The oceanographic and meteorological data have to be analysed and studied to find out the reasons for shifting of spawning season and its impact on the fishery of the following years.

RECOMMENDATIONS

The natural mortality of mackerel is very high and forms the major component of the total mortality. Natural mortality here includes loss due to the fish moving away from the fishing ground after a certain size. And since the life-span of the fish is small, it is necessary that the fish are caught when they are more abundant. Banerji and Chakraborty (1962) showed by defining a measure of fishing efficiency that at present the fishing efficiency is not significantly better than what would have been the case if the fishing was random. It has been shown that this inefficiency is not due to the inability of the fishermen to detect periods of high abundance and exploit them at the time but it is the result of lack of marketing, transportation and preservation facilities.

It is high time that an extensive survey of the offshore areas is made and also the nursery and spawning grounds found out. The measures of relative abundance of different year-classes in the catch must continue. The same work has got to be extended to spawning and nursery grounds when they are found out. Collection of chemical and physical data on a more intensive scale must be continued, both in the fishing and offshore grounds, and satisfactory methods of analysis developed. An analysis of abundance of various year-classes of the commercial catch must also continue to see if any changes in the natural and fishing mortalities are taking place. Increased use of mechanized methods for more efficient exploitation and exploration is recommended.

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4. SOME HYDROGRAPHIC FACTORS IN RELATION TO OIL-SARDINE AND MACKEREL FISHERIES

The hydrographic data for the 8 years from 1957 to 1965 have been averaged for each month for each 1 degree square and the special representation of each parameter is charted out (Figs 1-96). Only the surface data have been dealt with. The charts also show the average abundance and age-size composition of mackerel and sardines month-wise.

Temperature

During July the surface temperatures are low, the lowest of 25·4°C occurring off Cape Comorin. Along the entire west coast, in a narrow belt, the temperatures are never higher than 26°C. More or less similar conditions exist in August; by September the waters start getting warmed-up. By October, although the decrease of temperature coastwards is conspicuous, the rise of temperature from July is by 3° to 4°C; by November coastal temperatures are much higher than the previous months. The temperature gradients present during the previous months disappear and more or less a uniform distribution pattern is perceptible. During December, except for weak northward gradients between 17° and 19°N latitudes, the whole region from Cape Comorin to Ratnagiri presents a uniform temperature distribution. January presents a uniform temperature cells developed in the southern regions, although the special difference in temperature from 8° to 17°N latitudes is only 2°C. The waters get more and more isothermal with the progress of the year and uniform high temperatures exist along the coast. With the progress of summer the surface temperatures also increase. Thus during May a high temperature cell, with a core value of more than 30·6°C, is found between 11° and 12°N latitudes. In the regions off Bombay the waters are cooler, and weak gradients appear northwards. By June again in the southern regions indication is present as to the development of temperature gradients eastwards.

Salinity

During July salinity values are low (less than 32·5 ‰) in the coastal region of Cape Comorin to Mangalore. There is a definite increase offshore and values as high as 35·5‰ are found along the 75°E meridian. During August, with the same type of distribution, the coastal salinity values are still lower than those during July and by September the values show definite increase. In the southern regions a trend towards isohaline conditions is conspicuous. This trend is stabilized during October. With the beginning of the sinking phenomenon in December, the coastal salinity values are a bit lower than those of the offshore. High values, 35·5 to 36·0‰, are found in the northern regions off Bombay. During January again uniform distribution pattern is found between 7° and 14°N latitudes. But in the Karwar to Ratnagiri region, salinity gradients eastwards are still found to be as in winter. By the onset of summer, i.e. in February, March and April, the coastal salinity values show a definite increase and values as high as 35·5‰ are found off Karwar during April. May presents uniform distribution throughout the entire west coast, and by June there is a tendency towards decrease of coastal salinities.

Oxygen

Notable monthly changes in the distribution of dissolved oxygen at the surface are not at all observed. Wind and wave action result in thorough aeration of the surface waters. The range of oxygen values throughout the year varies from 4·3 to 5·1 ml per litre.

Sigma-T

During monsoon, owing to the influx of fresh water from the shore and the rains, the surface density values in the coastal regions are uniformly low. During this season it will not be correct to ascertain the movement patterns from the surface density values alone. These features prevail from July to September, and instead of the established southward drift, a weak northward movement is found in the surface layer up to September. Eddy structures predominate at the surface during October and November. The northerly movement, associated with the sinking phenomenon, is clearly observed in December; it takes up more well-defined pattern in January. During February and March this regular current system dissipates. During April and May more or less stagnant conditions exist along the west coast. With the approach of the monsoon again the low density belt along the coast develops in June.

ABUNDANCE*

Sardine

During July and August the abundance is low between Quilon and Cannanore, with a poor zone south of Quilon. Moderate abundance is found between Cannanore and Mangalore during July. During August the Calicut to Ponnani region is the moderate zone. After the intense monsoon during September, the abundance becomes moderate in the region Ponnani to Mangalore, the southern region still remaining low. Very poor abundance is observed in the region north of Mangalore during July, August and September. During October, the abundance is high in the region Alleppey to Mangalore, moderate zones being found intermittently.

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* In the text the terms used for the relative abundance of catch indicate the following ranges:

Poor	...	less than 500 kg	
Low	...	500 — 2,500 kg	Per 1,000 man-hours of fishing
Moderate	...	2,500 — 10,000 kg	
High	...	10,000 — 20,000 kg	
Very high	...	Over — 20,000 kg	

During November the abundance is moderate between Cochin and Mangalore, the northern regions yielding more than the previous months. December seems to be the peak fishing season along the entire west coast, very high abundance being observed in the region Mangalore to Malpe. By the end of winter, during January, the northern regions become much poorer than the previous months, and the southern regions, Mangalore to Quilon, become moderate to high. During February and March moderate to high abundance is observed from Alleppey to Malpe, with a poor zone around Cannanore during March. During April and May the abundance is much lower than the previous months, moderate catch being restricted to the region Alleppey to Calicut. The region around Cannanore still remains poor and with the onset of monsoon during June the fishery actually disappears along the coast, low to slightly moderate catch being observed from the region Alleppey to Ponnani. Except for the months October, November and December, during which low catch is found along the Maharashtra coast, the catch remains poor in the regions north of Malpe.

Mackerel

Mackerel fishery in July, along the entire west coast, seems to be poor except for low catch in the Alleppey region. Such conditions continue to prevail during August and September, except for a moderate catch in the region Ponnani to Calicut in September. By October, the fishery spreads over the entire west coast, the regions north of Mangalore up to Ratnagiri yielding moderate to high catches and the region south of Cannanore yielding low catch. With more or less the same trend in the southern regions, the fishery appears to be better in the northern regions during November, the region Ponnani to Cannanore yielding moderate catch. Similar to sardine fishery, December is the peak season when moderate to high abundance is observed along the entire coast. The abundance is reduced by January, moderate catch being observed in the regions from Ponnani to Calicut and from Kundapur to Karwar. During February the entire coast is depleted of this fishery, low catch being observed from Alleppey to Ponnani and in the Kundapur region. During March low abundance is observed in the regions Quilon to Calicut and Mangalore to Kundapur, and moderate catch in the region Kundapur to Karwar. During April, the fishery is poor along the entire coast, except for low catch observed in the regions of Alleppey and Kundapur. One particular feature in mackerel fishery is that it is mostly poor in the regions north of Karwar and south of Quilon, and the relative abundance of catch is high in the region Mangalore to Karwar. From May onwards, the fishery practically disappears from the inshore waters.

The sardine fishery appears to be good in the region Quilon to Malpe and the mackerel fishery from Calicut to Malvan. Thus, the northern regions appear to be better for mackerel fishery. In both the cases the peak season is in December. This may be attributed to the sinking phenomenon during this period, when the associated convergence causes dynamically a concentration of zooplankton in the region. During summer, April and May, although the sardine fishery appears to be of average standard in the southern regions, the high temperatures during this season do not favour the mackerel fishery. In both the cases, the fishery starts in the south (from Quilon) and gradually spreads northwards. From the density distribution it can be observed that the northward movement of current along the west coast starts by early December, and primarily this migration of the fisheries abundance can be correlated with this. During monsoon and post-monsoon, the lower temperatures near the coast seem to affect the mackerel fishery more adversely than the sardine fishery. The optimum temperature range for mackerel is from 27°-29°C, thereby showing that mackerel is more susceptible to slight temperature changes than sardine. The region off Mangalore, in general, is one where a sudden increase in salinity values (34 to 36 ‰) seems to be more favourable to mackerel than to sardine. Very low salinity values along the coast during monsoon do not, again, seem to favour the mackerel. During the active monsoon and the post-monsoon, the whole of the continental shelf is pervaded by colder waters due to upwelling; this phenomenon has maximum intensity between Calicut and Karwar. In these regions both the sardine and mackerel fisheries disappear during these said seasons. The mackerel fishery is more adversely affected than the sardine fishery during this period inducing these fish to migrate to some other regions. Although the surface oxygen values are high throughout the year, during the intense upwelling period, below a depth of 5 to 10 metres, the oxygen values are very much lower. This also may affect the migration of these pelagic fishes from the normal fishing zones. Moreover, upwelling causes vertical accelerations over the shelf and this probably may give rise to the formation of mud banks along this coast. These mud banks form a sort of barrier to the drastic wave action during monsoon and form a calm zone where the fishes can accumulate avoiding the rough seas. The fishery in the mud banks is quite appreciable during monsoon also.

5. BIOLOGY AND FISHERY OF LESSER SARDINES OF INDIA

The local names of lesser sardines (*Sardinella* sp.) vary from place to place and from species to species. But in several centres no attempt is made to differentiate one species from another by giving them different names, particularly so when the seasons of catch of the species is the same and when there is no appreciable difference in the size range of the species involved.

	S. gibbosa	*S. albella*	*S. fimbriata*
Bombay—Ratnagiri area ...	*Tharli*	*Tharli*	*Tharli*
Goa	*Pedvi*	—	*Pedva*
Karwar and Mangalore	*Pedi* and *Frebai*	—	*Pedi* and *Frebai*
North Kerala	*Chala mathi*	—	*Chala mathi*
South Kerala	*Mathi chala*	—	—
Tamil Nadu	*Choodai*	*Choodai*	*Choodai*
Andhra Pradesh	*Kavallu*	—	*Kavallu*
Orissa	*Kavallu*	—	—

BIOLOGY AND FISHERIES

General

The different species of *Sardinella*, other than *Sardinella longiceps* (Cuv. and Val.), contributing to local fisheries in several centres on both the coasts of India are commonly known as lesser sardines. The importance of lesser sardines as an independent fishery is eclipsed by the enormous catches of oil-sardine on the south-west coast. Here these food-sardines, which account for nearly 5 per cent of the total marine landings, contribute appreciably to the fishery wealth of upper west coast and to the entire east coast of India.

Sardine fisheries are subjected to large fluctuations in abundance all over the world. The lesser sardines are also affected by large annual variations in abundance (Table 1), but the setback is much less pronounced than that of the oil-sardine fishery.

TABLE 1. LESSER SARDINES OF ANNUAL LANDINGS (1962-1966)
(SARDINES OTHER THAN OIL-SARDINE; IN TONNES)

State	Year				
	1962	1963	1964	1965	1966
1. Andaman Island	16	15	18	22	29
2. Andhra Pradesh	7,784	7,228	5,955	9,512	31,266
3. Goa	NA	NA	NA	87	5,552
4. Gujarat	40	8	26	18	6
5. Kerala	3,889	9,310	13,808	18,962	8,680
6. Madras (including Pondichery) ...	5,847	8,119	16,169	10,225	13,924
7. Maharashtra	689	230	479	1,082	934
8. Mysore	237	1,331	2,053	778	1.112
9. West Bengal and Orissa	1,049	932	1,890	2,084	3,140

NA=Not available.

Species Composition

In Indian waters, 9 species of *Sardinella* are commonly recognized (Nair, 1953), but not more than 4 species support the commercial catches. These are: *Sardinella fimbriata* (Val.), *Sardinella albella* (Cuv. & Val.), *Sardinella gibbosa* (Blkr.) and *Sardinella sirm* (Rup.). Except for the last-mentioned species which enjoys only very limited distribution in the extreme southern zone of peninsular India, the others contribute to localized fisheries which often overlap one another in their areas of abundance. *Sardinella melanura*, another species which occurs in small numbers throughout the year along the Coromandel Coast (Vijayaraghavan, 1953), enters the fishery along with *S. fimbriata* and reveals a very restricted distribution. The adoption of specific name *Sardinella jussieu* (Lace.) for *Sardinella gibbosa* (Blk.) is still inconclusive and hence in this account the latter specific name is followed to avoid confusion in the recognition and naming of the species.

Racial and Biometrical Data

Different species of lesser sardines, particularly in the early juvenile stages, resemble considerably with each other. This necessitates comparison of various characters to check the validity of species. Since some species enjoy discontinuous distribution supporting independent fisheries in several localities, it is likely that different races or independent populations exist and sustain the local fisheries. Sam Bennett (1962) compared by methods of regression analysis such morphometric characters like head length and snout to insertion of anal of fish collected from the Palk Bay and Gulf of Mannar. Based on these observations he suggested that the significant differences observed between the same species of *S. albella* from the two centres may be due to changes in the environment.

Dutt (1959, 1961) carried out statistical analysis on meristic characters of *Sardinella gibbosa* (Blkr.) and concluded that detailed analysis of these did not so far indicate the existence of distinct groups, but the differences between the means were significant with regard to the prehaemal vertebrae, tail vertebrae and number of pectoral fin-rays. He also found that complex vertebrae occur more frequently in *S. gibbosa* than in *S. fimbriata* and that the 2 species differ markedly in the total number of vertebrae, in the number of pectoral fin-rays and in the number of gill-rakers along both the arms of the first gill-arch. The number of pectoral fin-rays are less in *S. gibbosa* than in *S. fimbriata*. The average number of gill-rakers on both the arms of the first gill-arch (of the left side) in the different centimetre groups in *S. gibbosa* are distinct from those of *S. fimbriata*.

A paper " On the juveniles of *Sardinella fimbriata* (Val.) and *Sardinella gibbosa* (Blkr.) " (Dharmamba, 1963) deserves special attention. In this the author has shown that these 2 species could be distinguished from one another by the number of post-ventral scutes possessed by them and also by the difference in the pattern of distribution of black chromatophores on the surface of the tongue. *S. fimbriata* has a lower mean number of post-ventral scutes (13·72) and *S. gibbosa* a higher mean (15·02). These numbers do not vary with the size of the fish as is the case with the gill-raker. In *S. fimbriata*, black chromatophores are present at the base of the tongue with the rest of the surface clear and/or as small groups at one or two places at the base. In *S. gibbosa* the black chromatophores are distributed all over the surface of the tongue in a haphazard manner. A table of summary of all the characters in which *S. fimbriata* differs from *S. gibbosa* has also been given in this paper.

The possession of teeth on the tongue by *S. gibbosa* (Blkr.) and their absence in the case of *S. jussieu* is given as a distinguishing character between *S. gibbosa* (Blkr.) and *S. jussieu* (Lacepede), which were considered as synonyms (Fowler, 1941; Munro, 1955).

Maturity, Spawning Grounds and Larval Ecology

The lesser sardine fishery, by and large, is a fishery supported by the 0-year class, although mature specimens and groups of larger size support and supplement the main fishery at several centres, particularly in the Goa zone (Hamre *et al.*, 1966; Alikunhi *et al.*, unpublished). In the Bombay-Malwan zone the lesser sardine fishery is supported by immature and maturing species of *S. fimbriata* and *S. albella* (Kaikini, 1960). The fishery in Marmagao is supported by *S. gibbosa* and *S. fimbriata*; the former are immature and maturing at the beginning of the season, whereas *S. fimbriata* are much advanced in maturity in the commencement period of the fishery itself. It is very likely that the 1-year class substantially contribute to the catches towards the fag end of the season in the case of both *S. gibbosa* and *S. fimbriata*. In the southern and south-eastern centres also the fishery is supported by juveniles. Ganapati and Rao (1957) and Dharmamba (1959) studied the maturity and spawning habits of *S. gibbosa* from Waltair. The bulk of the fishery is contributed by immature specimens. Mature specimens were available in the catches only from February to May, but spawners were never encountered. Spent fishes have been observed from April onwards, indicating a prolonged spawning season for the species. Dharmamba (1959) also observed that there is only one mode formed by each of the high-maturing ova which are sharply separated from the rest of the stock of eggs, that spawning in *S. gibbosa* should be restricted to a definite period and that probably each individual spawns only once during each season. She further stated that the curve of frequency polygons of ova from the ovaries of 3 different individuals in the same stage of maturity indicated that there may not be variation in the periodicity of spawning between individuals of species. Dutt (1961) commenting on the occurrence of particular length groups during 2 distinct months of the season, with an interval of at least 3 months in between, suggested the possibilities of 2 distinct spawning periods or spawning groups in *S. gibbosa* off the central part of the east coast of India. He stressed the need for a thorough examination of the existence of 2 races or populations, one with spawning grounds off Waltair and another elsewhere with a spawning period, about 4 months earlier to February-April. He also stated that ripe and running adults between 120 and 180 mm had been obtained from February-April period in waters close to the shore. Bhavani (1954) indicated the existence of spawning ground of *Sardinella* spp. off Waltair.

No maturing or mature adults of *S. fimbriata* were obtained at any time at Waltair, although 'empty adults' were observed towards the end of the season (Dutt, 1959).

The breeding season of lesser sardines is from February to June. *S. albella* and *S. gibbosa* spawn at the end of the first year of growth. Early juveniles, 26-85 mm in size, are found along Waltair Coast during March to May (Dharmamba, 1963).

Larval History

Chacko (1950) described the eggs of *S. gibbosa*. The eggs have a diameter of 0·68-0·84 mm with frothy yellowish yolk and a small oil-globule. Bapat (1955) isolated the eggs of *S. fimbriata* from the Gulf of Mannar and Palk Bay and found it agreeing with the description given by Delsman (1926) of eggs and larvae of *Clupea fimbriatus*, except that the eggs recorded from Indian coasts are smaller in size and (according to him) are spherical, transparent and coarsely vacuolated. The egg also measured 1·238-1·339 mm and the single oil-globule is 0·999 mm in diameter. A large peri-vitelline space is also characteristic.

Fishing Season, and Fishing Craft and Gear

The lesser sardine fishery commences in the Bombay region as soon as the vigour of the south-west monsoon is over. Medium-sized *Sardinella fimbriata*, locally called *tharli*, occurs in moderate quantities in the shore seine and bag net (*bokshi*) catches of Versova and neighbouring fishing centres, along with other Clupeoids. The fishery is more distinct and important in Malwan (Kaikini, 1960) where *S. albella* and *S. fimbriata* dominate the catches. Shore seines and gill nets are used in the operations.

In Marmagao and other centres in Goa, the fishery of the lesser sardine is only next to that of *Rastrelliger*, and large quantities are landed with the help of purse seines and shore seines. The fishery commences in September-October and lasts up to February. *Sardinella gibbosa* and *Sardinella fimbriata* dominate the catches. Large and numerous shoals of sardines are encountered every day at the mouth of river Mandovi and up to 15 fathom depths during November-December. Purse seines and boat seines are operated only after sighting the shoals. Purse seines are laid out in such a way that they encircle the shoals not only all around but also from underneath making it difficult for the shoals to escape even if the fish move to the bottom.

In the Karwar-Mangalore zone, the *pedi* and *frebai* fishery of lesser sardines are exploited by *rampan*, *yendi* and *gorbale* and other types of shore seines, cast nets and also *pattle bale* (gilling drift nets) bringing only the groups of larger size along with larger specimens of other clupeoids and scombroids. Boat seines (*paithu vala*) and shore seines commonly used in the oil-sardine fishery are also used for the lesser sardines in the Kerala zone. In both, the fishery lingers throughout the post-monsoon period with occasional periods of lull, the more important fishing season being from September to February (Venkataraman, 1960). All along the west coast fishermen use, under necessity, the same gear for all pelagic fishes and often go prepared for catching mackerel, oil-sardines and lesser sardines, whichever is available on that day. If all the 3 varieties are available, they prefer mackerel to sardines and oil-sardines to lesser sardines.

On the south-eastern coast the *choodai* fishery of lesser sardines are exploited by means of shore seines, boat seines and gill nets (Sekharan, 1959). According to Sekharan (1959) hand nets with torches and shore seines are operated from dug-out canoes up to a distance of 4·8 km from the shore. Catamarans and Tuticorin-type boats operate boat seines and gill nets up to 12·8 km from shore. The very young fish below a modal length of 50-54 mm are caught by torch and hand net boats. Shore seine catches are mainly of the 0-year class (up to 75 mm) and gill net catches of 1-year and older groups. The fishery commences in late March and extends up to November, by which time Palk Bay becomes rough for operation. Young sardines are available up to June and are caught by hand nets and also by shore seines. Gill nets take the larger size groups after July till the end of the season. The largest modal length groups in gill nets are 110-114 mm in case of *S. albella* and 125-129 mm in case of *S. gibbosa*. A single shore seine haul lasting 3 hours may land as much as 12 tons of lesser sardines (Sekharan, 1967). According to Sam Bennett (1962), the fishery is active from April to October in Palk Bay and from November to March in the Gulf of Mannar. He found *S. albella* more abundant in Palk Bay, and *S. gibbosa* in the Gulf of Mannar.

The lesser sardine fishery in the upper and middle east coast zones are different from Mandapam area. In Kakinada-Uppada zone, the season is from December to May with a peak period in January and February (Muthu, personal communication), whereas in Waltair the season is from October to June (Ganapati and Rao, 1957). *S. fimbriata* appears earlier in the season and accounts for the major portion of the catches. The position gets reversed by the end of the season. The shore seines land most of the catches during October to January and are composed of the 0-year class fish. Gill nets (*kavala vala*) are used for the larger size groups (100-180 mm) during January and February and the shore seine catches for fishes between 50 and 100 mm in length. On the whole *Sardinella gibbosa* is less common than *S. fimbriata* along the Waltair Coast.

On the Madras Coast, sardines occur during the month of March and April (Basheeruddin and Nayar, 1962). Smaller-sized specimens of *Sardinella fimbriata* with a size range of 40 to 100 mm, with a dominant size of 60 mm, and *Sardinella sirm* with a smaller size range of 30 to 60 mm support the fishery. The catches are obtained from shore seines and are often miscellaneous catch comprising juveniles of various other groups of fishes.

Age, Growth and Recruitment

The *choodai* fishery of Mandapam comprising *S. albella* and *S. gibbosa* was studied in detail with special reference to age, growth and recruitment into the fishery (Sekharan, 1955, 1959, 1967; Sam Bennett, 1962). The lesser sardine fishery draws its support mostly from the juveniles, i.e. the 0-year class. The contribution of older year classes to the bulk of the fishery is rather small and it is very unlikely that fishes older than 2 years enter the fishery at all. In the 0-year class, the growth rate has been estimated to be about 40 mm in a period of 7 months for *Sardinella albella*. The modal size of 1-year-old fish is 107 mm. In *Sardinella gibbosa*, a growth of 55 mm is shown in 8 months for younger fish under 100 mm. Length of 1-year-old fish is about 107 mm. The maximum length of *S. gibbosa* recorded at Mandapam is 139 mm (168 mm total length). From an analysis of the length frequency distribution, Sekharan (1959) observed that *S. albella* measures 100–110 mm, whereas *S. gibbosa* measures 100–120 mm at the end of 1 year.

The factors that influence the size composition of catches are primarily the fishing methods. But a comparison of the length groups taken by gill nets and shore seines revealed a real differential distribution of the size groups. When bigger length groups are obtained in gill nets which are operated offshore, the shore seines do not reveal these large length groups. This may perhaps be due to the fact that older sardines prefer to remain in the deeper waters away from the shore and may be independent of mesh selection. A knowledge of this behaviour should be of assistance in the rational exploitation of the bigger fishes. The effect of torch-fishing with hand nets (bringing smaller-size groups) on the larger sizes is not known.

Gnanamekalai (1962) described in detail the bionomics of the sardine *Sardinella sirm* which contributes to the valuable fishery in the Tuticorin area from October to March. The commercial catch consists of fishes in the size range of 140–250 mm, with a dominant group of 170–180 mm. The rate of growth averages 10–12 mm in a month, but a rapid growth rate of about 20–30 mm is seen in the month prior to spawning. The fish reaches maximum size of 250–250 mm in about one and a half years and grows to about 140 mm at the end of the first year.

Sardinella sirm attains maturity when it is 140–150 mm in length and spawns more than once in the same season.

Food and Feeding Relationship

The lesser sardines are plankton feeders (Ganapati and Rao, 1957; Sekharan, 1959; Sam Bennett, 1962). Copepods and diatoms form the main constituents in the diet of the adults. According to Bapat and Bal (1950) larval and post-larval fishes feed mainly on copepods. Different species of copepods, pteropods, larval bivalves, fish larvae, diatoms, sergestids and larval decapods are cited by Sam Bennett (1962) as food organisms of *S. albella*. Vijayaraghavan (1953) considers *S. albella* to be a surface feeder and plankton predator.

Although there is no doubt that the lesser sardines, juveniles and adults are plankton feeders, there is not sufficient evidence to prove that they prefer any particular species of plankton organism. It is also not known whether they are exclusively filter feeders or whether they pick and choose any special item of food, although Ganapati and Rao (1957) showed that *S. gibbosa* is predominantly a zooplankton feeder, and that there is no complete correspondence between the planktonic composition and stomach contents with respect to the relative abundance of the different types of organisms. It is to be presumed that selective feeding is exercised, involving active efforts on the part of the fish, though the fish is generally believed to be a filter feeder. For a correct assessment of food in relation to selective feeding, a careful study of actual food elements of fish with special reference to available food in the actual environment is necessary (George, 1964). Variations in the gut elements could most probably be due to variations in the availability of ' edible plankton ' in different seasons and at different centres unless the species is a definite selective feeder.

Factors that influence the shoreward movement of young fishes with special reference to availability of food are not fully known. According to Ganapati and Rao (1957) the beginning of the sardine fishery in October coincides with the minor plankton peak during this period, and that the peak period of sardine fishery itself coincides with the major phytoplankton peak. Dutt (1959) stated that the juveniles of *S. fimbriata* enter the inshore waters along the Waltair Coast in October, and remain there up to May for a period of intensive feeding and growth. But the intra-seasonal variations and the earlier commencement of the fishery in certain years are yet to be studied in relation to availability of food. Prasad (1958) pointed out negative influence of *Noctiluca* on *choodai* fishery. Bhimachar and George (1950) observed that along the west coast of India, sardines and anchovies did not appear in ' Red water ' caused by *Noctiluca*, and that when these swarm in the region the sardine and mackerel fisheries suffer an abrupt set-back.

Slight difference in growth rates of lesser sardines in different years has been noted from the Mandapam area (Sam Bennett, 1962) and from Waltair Coast (Dutt, 1959, 1961). These are attributed to changes in environmental conditions. It is natural that food should play an important part in the environmental conditions. Other physical and chemical conditions in the sea can also bring about favourable conditions for fish to come near the shore. Hydrographical conditions are, according to Ganapati and Rao (1957), more favourable during the northerly current system in the January-June period, when there is enrichment of the surface waters by upwelling of the subsurface waters. The northerly current also brings in the enriched oceanic waters of the bottom Antarctic drift during the fishery season into the Vizagapatnam Coast.

The influence of winds and currents as a direct factor for the movement of shoals into the fishing grounds has also been indicated. Fishermen depend to a great extent on the direction and intensity of prevailing winds to forecast the fishery. In Mandapam area during May to September the wind blows from the south, and when there is a strong south-northerly wind *choodai* from the northern waters move southwards and enter into the fishing waters of Palk Bay. Fish shoals come close to the shore in the Gulf of Mannar when there is strong wind in the northsoutherly direction (Sam Bennett, 1962). *Choodai* are absent from the fishing grounds when the incidence and velocity of winds are high as in the monsoon periods. Hence wind direction and velocity appear to be important in contributing to better catches in Mandapam area.

FUTURE LINE OF WORK

The lesser sardines comprise closely related species. The present information on the distribution points towards abrupt breaks and overlapping in the distribution of the species. A field key for quick and correct identification of lesser sardines is a prerequisite for a clear distribution map of lesser sardines. Active workers in different zones may report back on the species composition based on re-checking of species which when available could be used for a reliable distribution chart for lesser sardine.

It is likely that some of the species of *Sardinella* support independent fisheries and could be clearly marked races of the same species. Morphometric as well as physiological characters have to be studied in detail and the pattern of distribution and behaviour of such races have to be highlighted.

To improve the catches, attempts have to be made to bring more areas under fishing. Use of gear, independent of shore, could be considered to minimize the availability problem, particularly during the lean years. Increased use of gill nets may improve the size composition and of boat seines increase catches. But the effect, long and short range, on the shore seine catch of young juveniles requires constant watch with an eye on any possible deleterious effects on the total fishery and economy of the fishing community.

In India, fishery of adults and spawners of lesser sardines does not exist. Hence any increase in effort on the fishery for juveniles cannot have repercussions on the fishery at other centres, except when the spawning population goes below the critical level which it cannot perpetuate itself to original levels.

The gradual introduction of purse seines all along the coast for exploratory fishing and for fish behaviour studies should be encouraged. Search for schools in the periphery of the present zones of fishing and also before and after the conventional seasons should be intensified. Deployment of more effort in the offshore zone should be considered.

The eggs and larvae of most of the species are not isolated and studied in detail. This has to be taken up at centres where mature fish is available.

A 0-year class fishery, like that of the lesser sardines, could give rise to sharp fluctuations, as the success of the fishery entirely depends on the success of current year's spawning. Adverse environmental conditions could bring about mass mortality of larvae and juveniles, causing large variations in the numbers recruited into the fishery. A full knowledge of the rate of success of spawning could help in the prediction of the probable size of the fishable stock for the immediate season. The information could be gathered in stages, viz. mapping the spawning grounds, carrying out egg and fry surveys, and collection of statistics on the catch trend of the early juveniles. The last one itself is an index of the success of survival of young fish during the season.

The pattern of winds in directing shoals into the fishing grounds are not properly understood. This has to be studied in detail.

The pattern of breeding including possibility of distinct spawning periods or spawning groups is not properly understood in lesser sardines. A better understanding of the spawning behaviour can explain the occurrence of same size groups in different months of the year.

The actual role of planktonic food as an inducement in shoreward migration has to be investigated, and the actual food has to be studied in relation to available food in the environment.

The pattern of migration, parallel to shore or inshore-offshore migration or both, and limits of distribution can be better understood by tagging and mark-recovery studies carried out from all the important centres on both the coasts. The national programme in tagging of mackerel and sardines initiated in 1967–68 season has to be strengthened, recovery programme highlighted and pursued as a continuous programme of investigations in the succeeding years till adequate information is gathered on all aspects of growth, and migration understood. The information on length frequency collected during the season as part of the tagging programme or otherwise has to be pooled, processed and interpreted.

The short- and long-range effect of upwelling and other oceanographic phenomena on the fluctuation and availability of sardines should be studied at all centres where facilities are available.

An annual meeting of the leaders of teams of workers in sardine biology may be arranged sufficiently early in the season to take stock of targets achieved and for planning team-work for the following season, allotting priorities of work according to the facilities available at the various centres or zones.

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EXPLANATION OF FIGURES

Figs 1–12. Distribution of surface temperature, relative abundance of oil-sardine, their modal sizes and year classes from July to June.

Figs 13–24. Distribution of surface salinity and relative abundance of oil-sardine from July to June.

Figs 25–36. Distribution of surface oxygen and relative abundance of oil-sardine from July to June.

Figs 37–48. Distribution of surface density (σt) and relative abundance of oil-sardine from July to June.

Figs 49–60. Distribution of surface temperature, relative abundance of mackerel, their modal sizes and year classes from July to June.

Figs 61–72. Distribution of surface salinity and relative abundance of mackerel from July to June.

Figs 73–84. Distribution of surface oxygen and relative abundance of mackerel from July to June.

Figs 85–95. Distribution of surface density (σt) and relative abundance of mackerel from July to June.

Relative abundance

(Catch/1000 man hours)

< 500 kg

500 - 2,500 kg

2,500 - 5,000 kg

5,000 - 10,000 kg

10,000 - 20,000 kg

> 20,000 kg

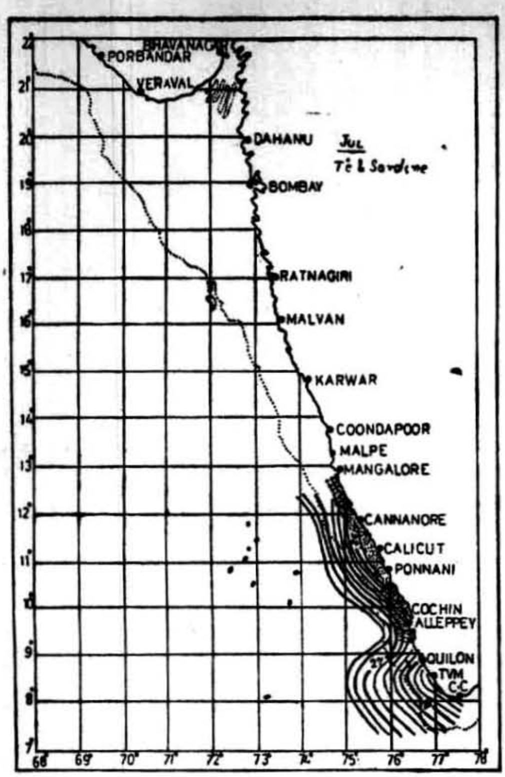


FIG. 1

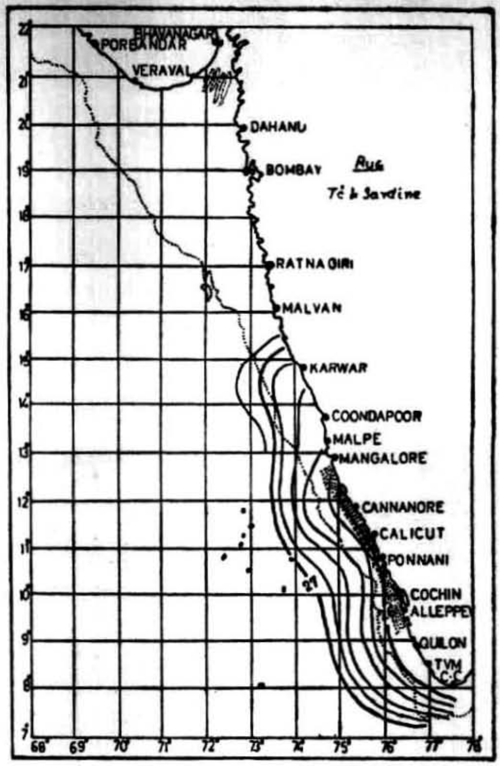


FIG. 2

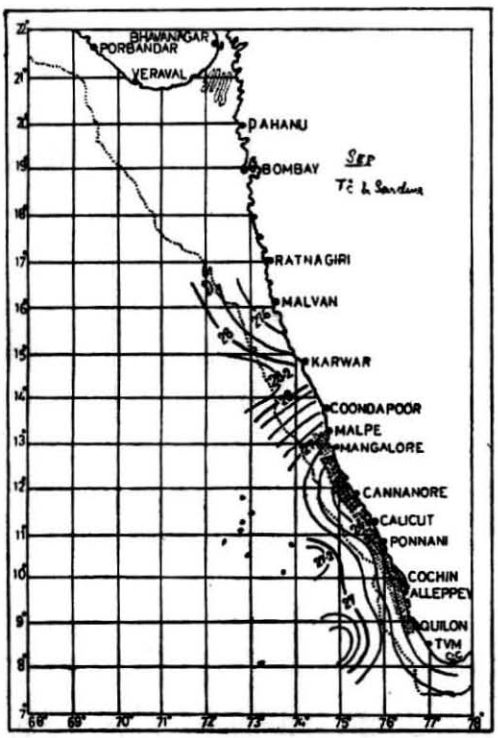
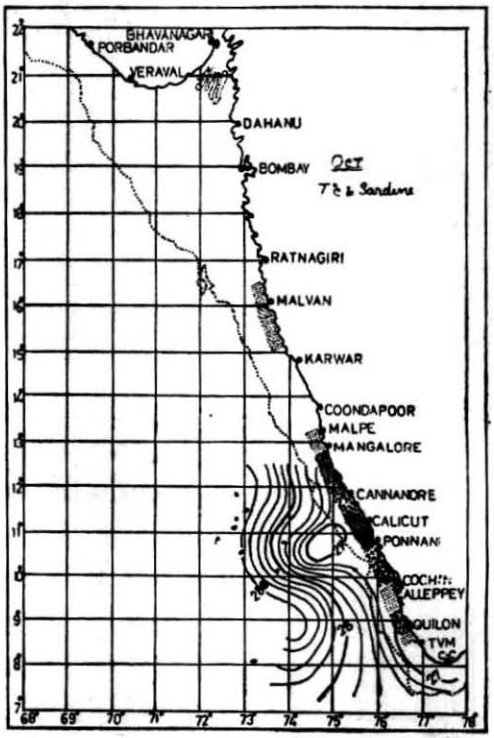


FIG. 3



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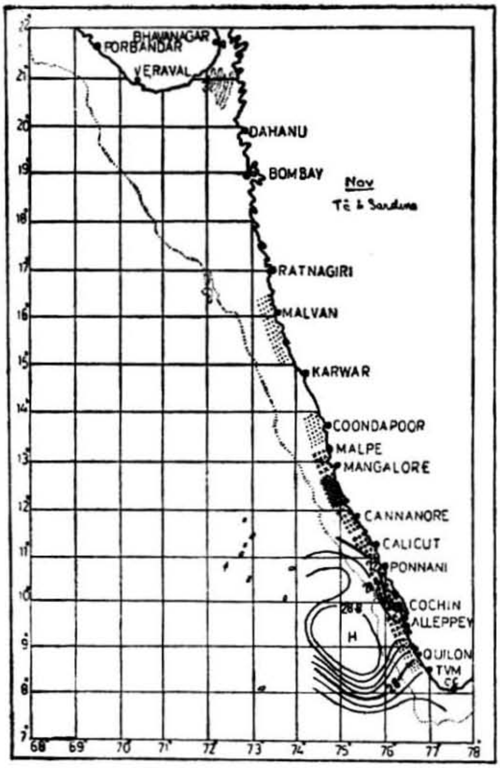

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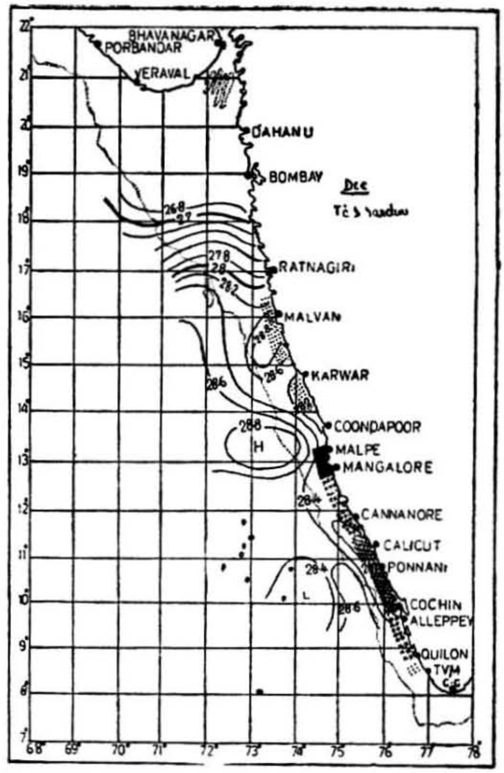

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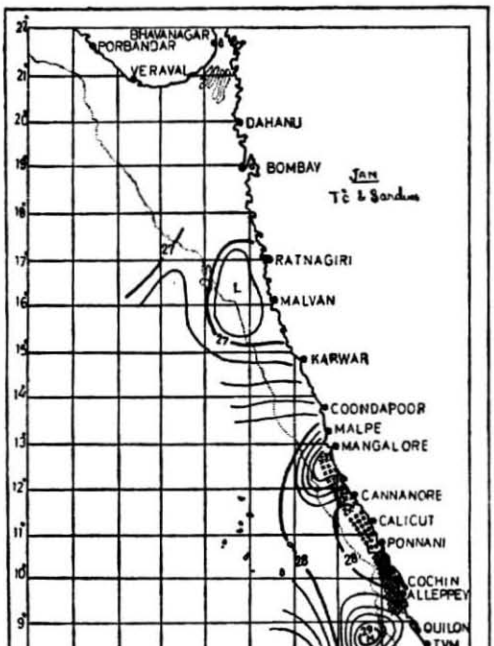

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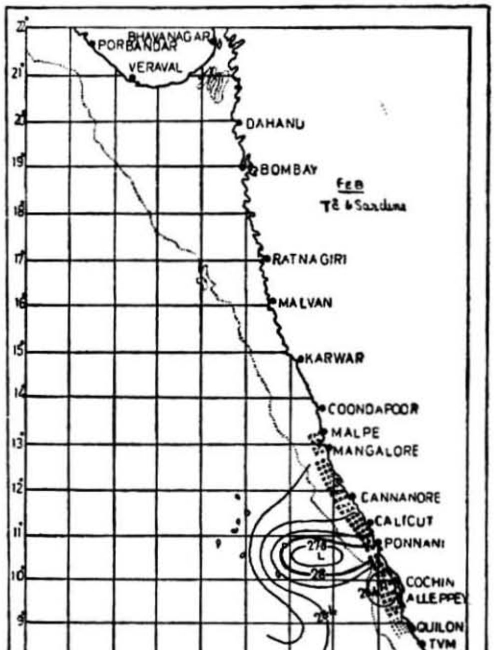

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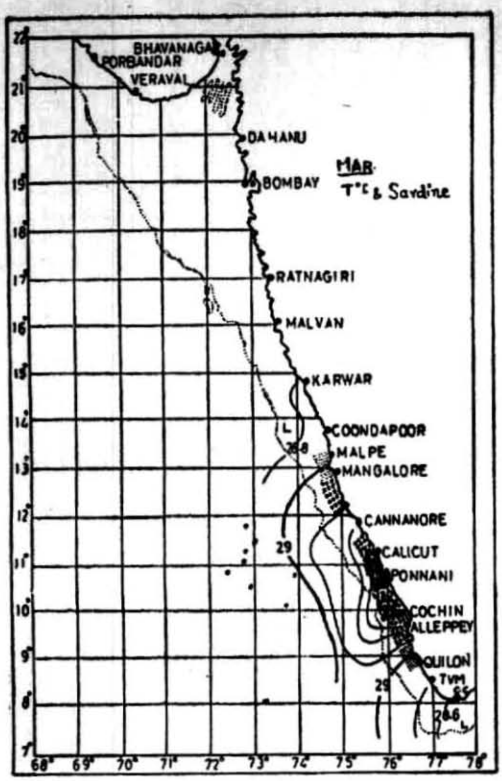


FIG. 9

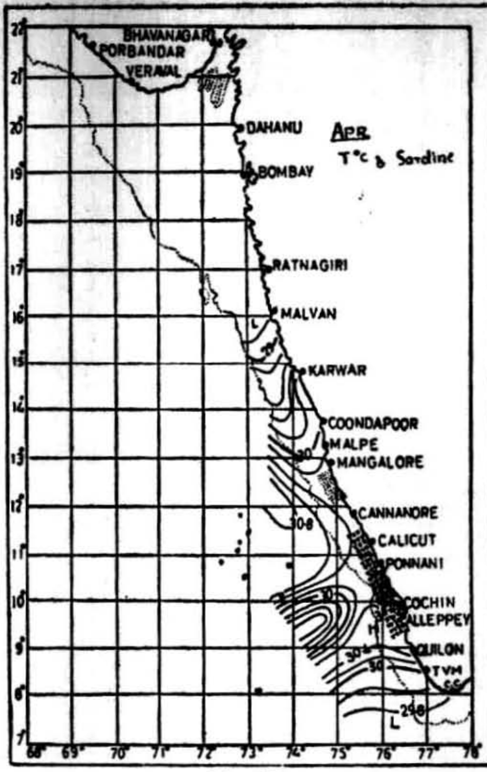


FIG. 10

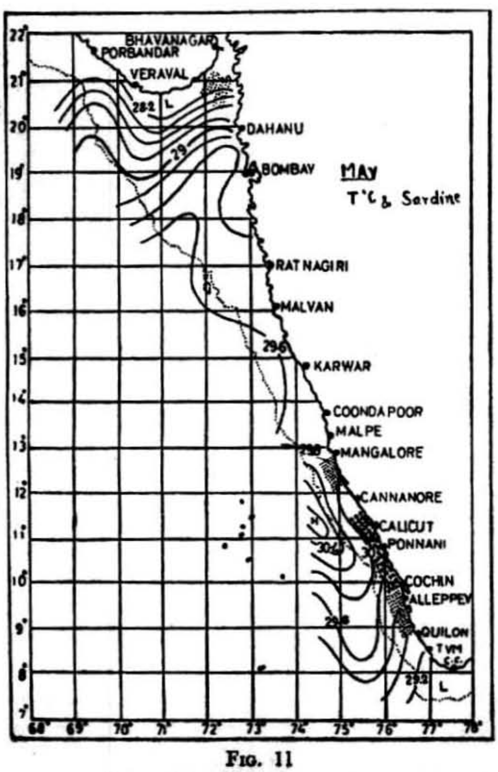


FIG. 11

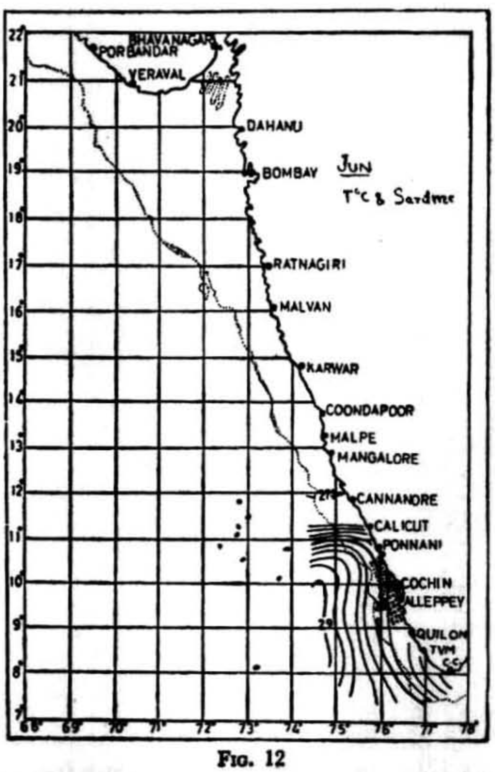
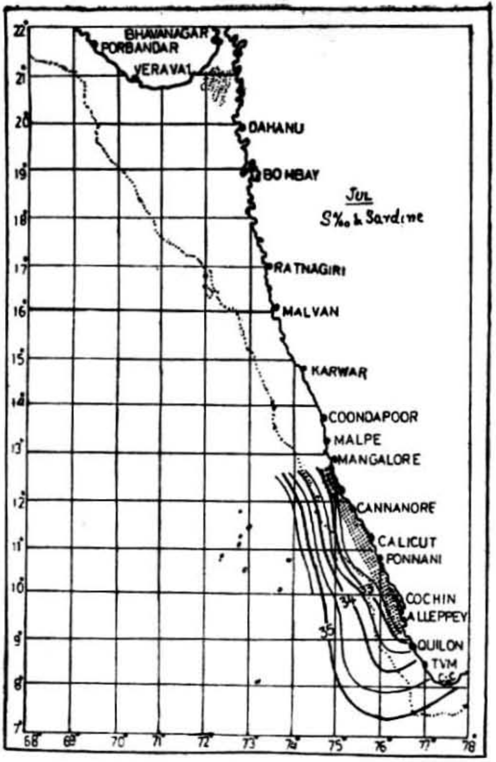


FIG. 12



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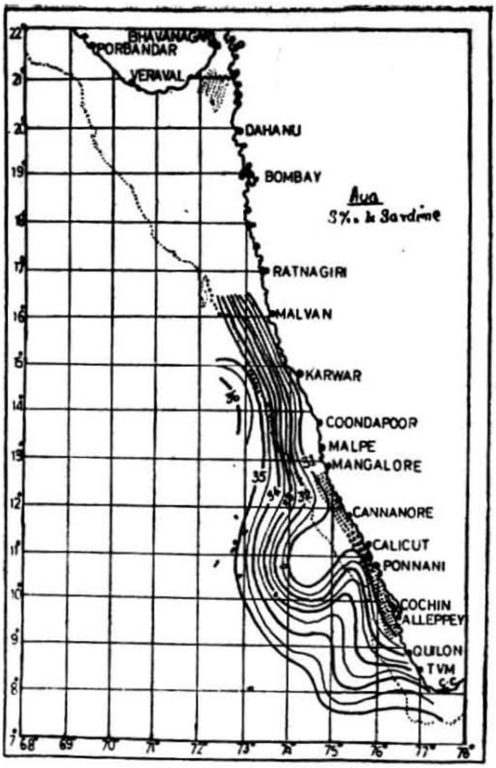

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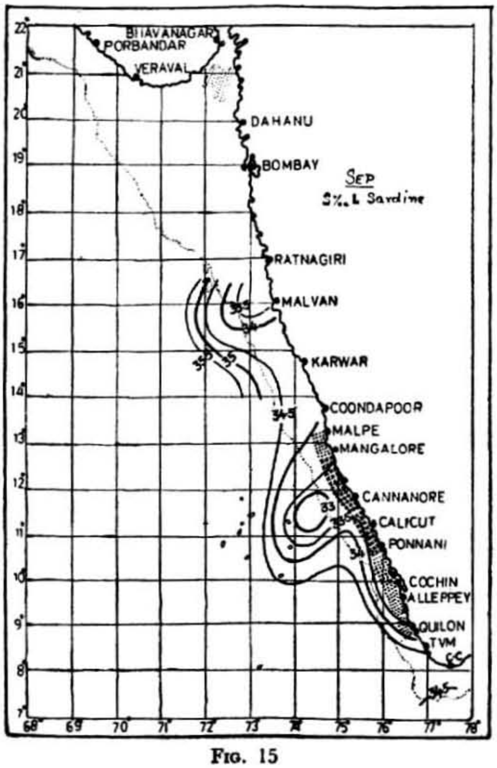

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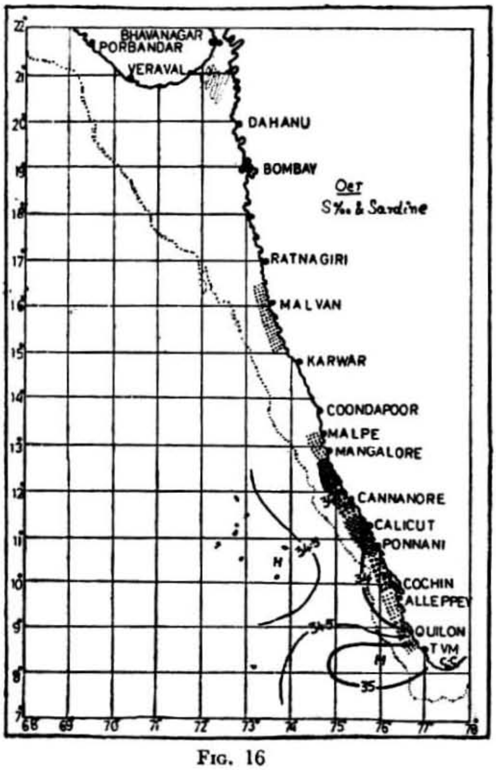


Fig. 16

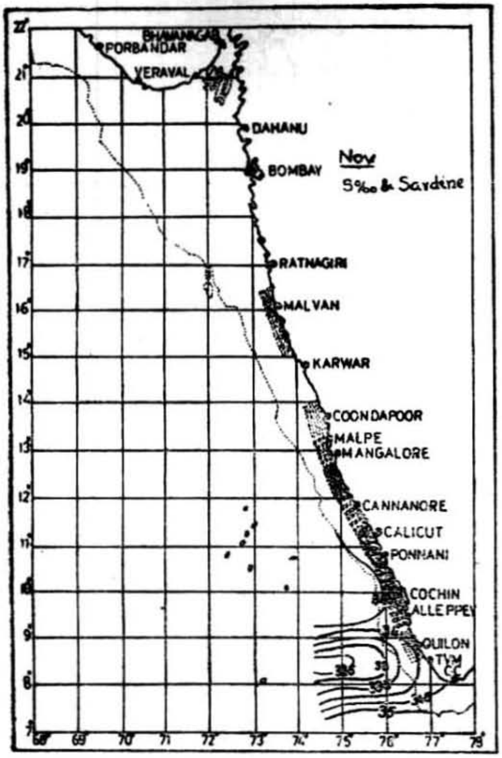
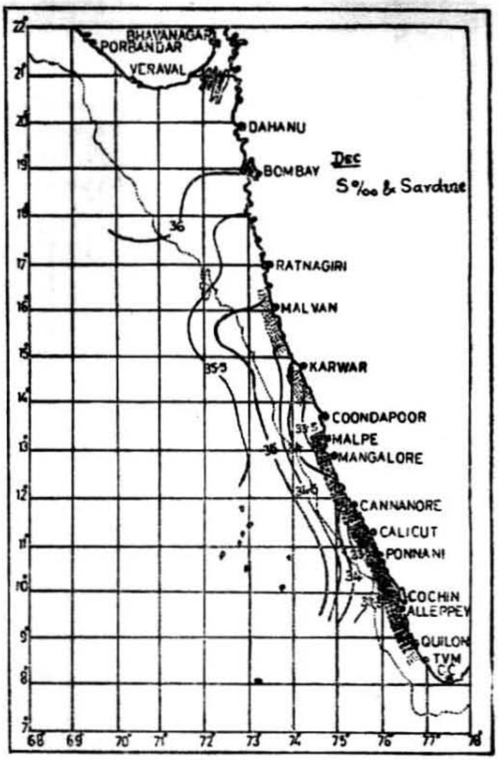


Fig. 17



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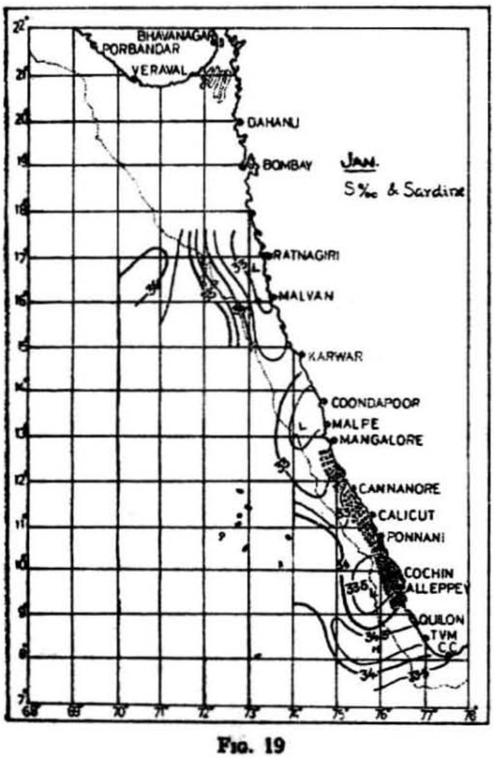

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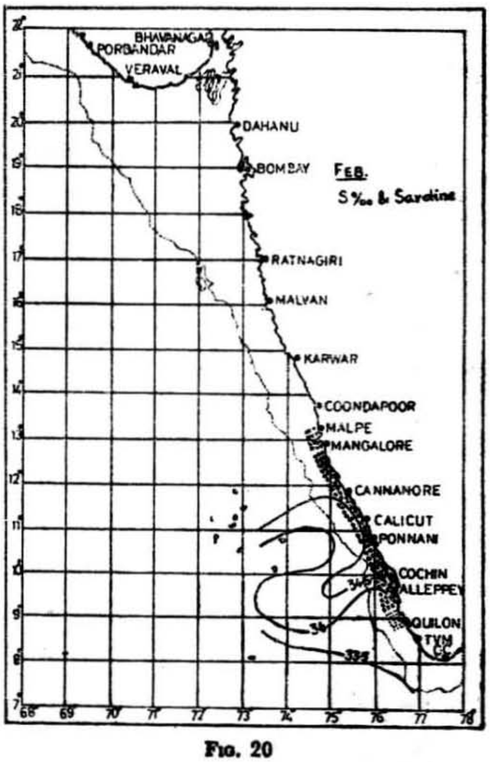

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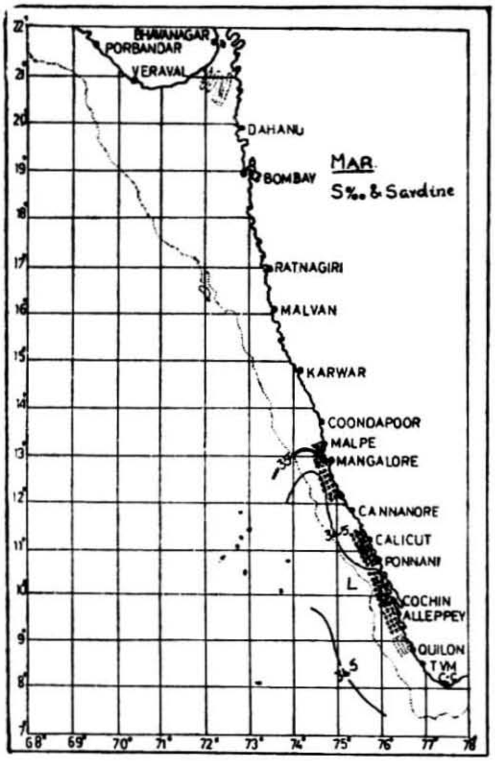

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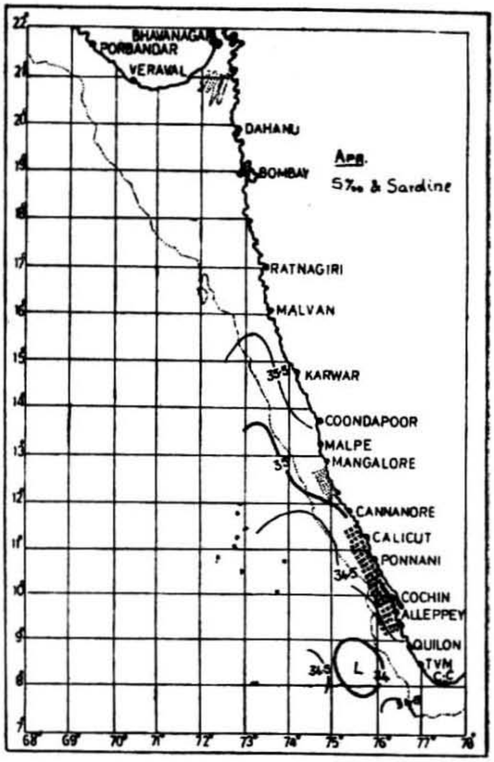

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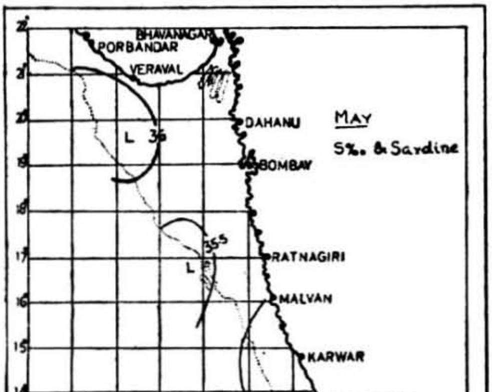


Fig. 23

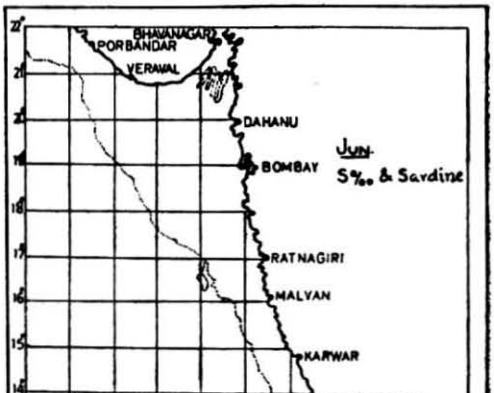


Fig. 24

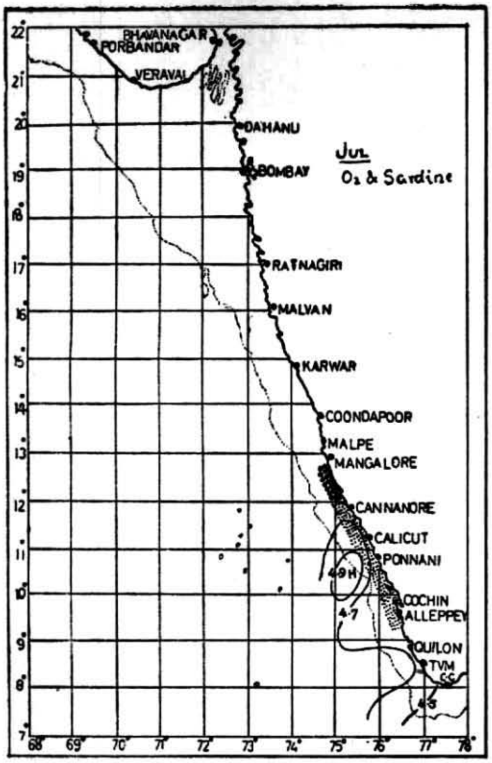
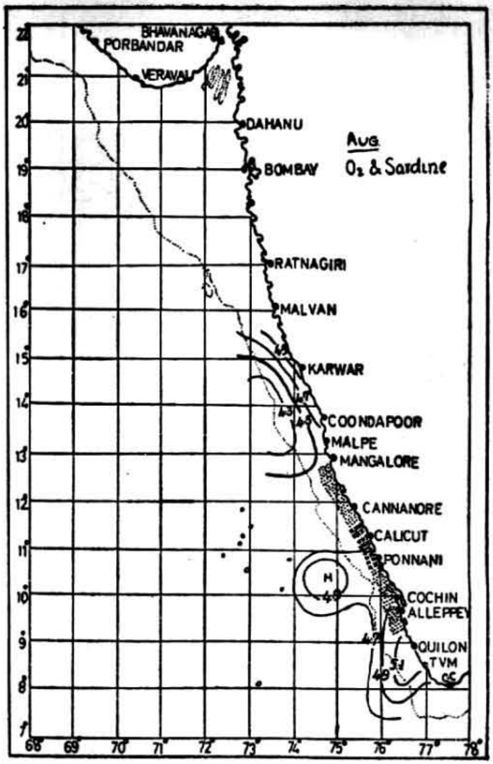


Fig. 25



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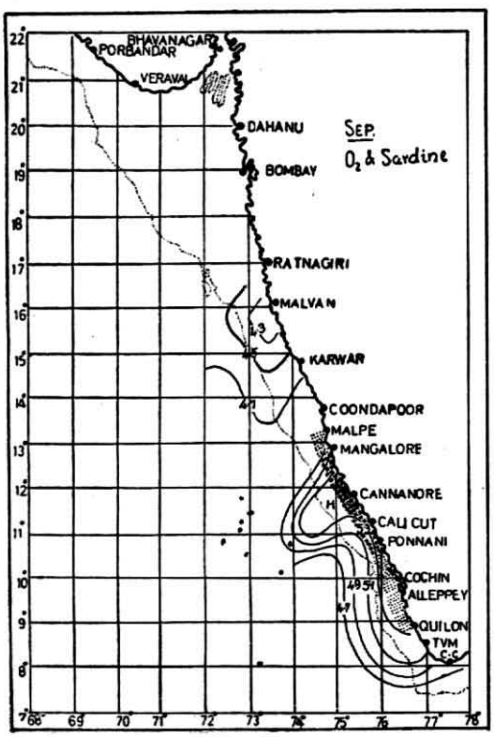

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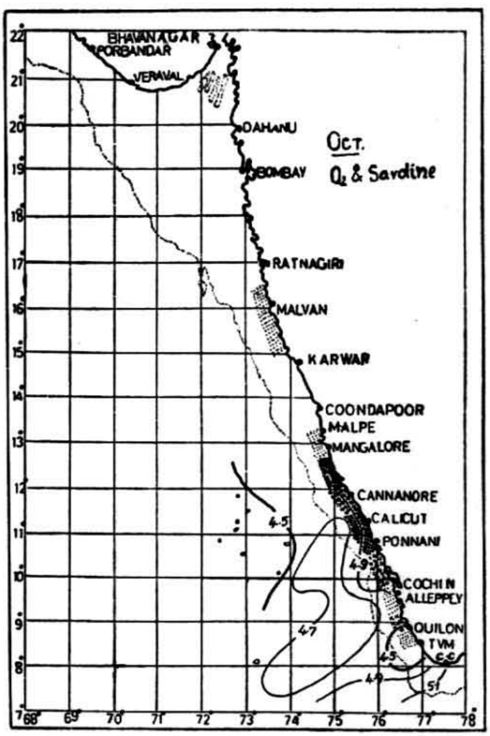

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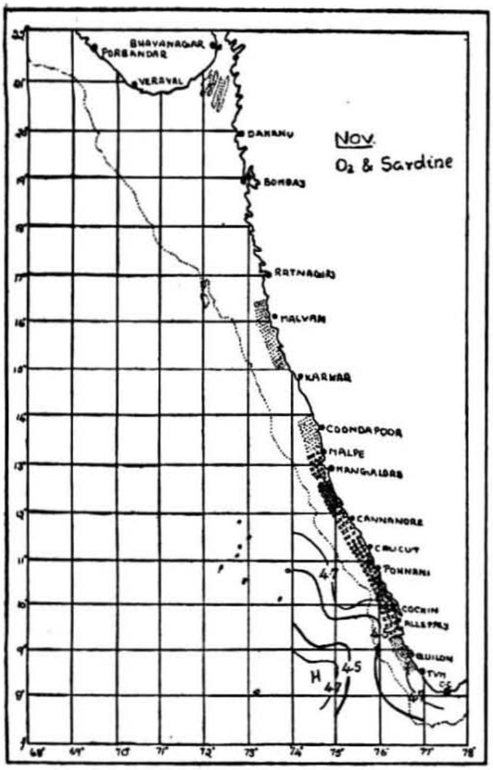

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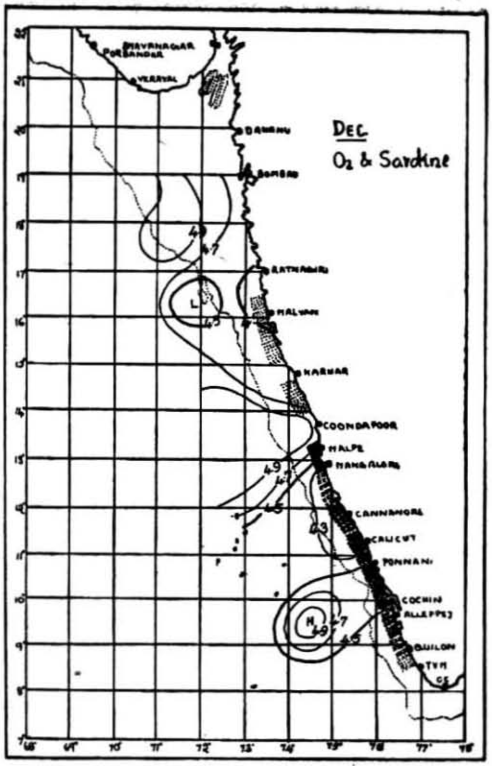

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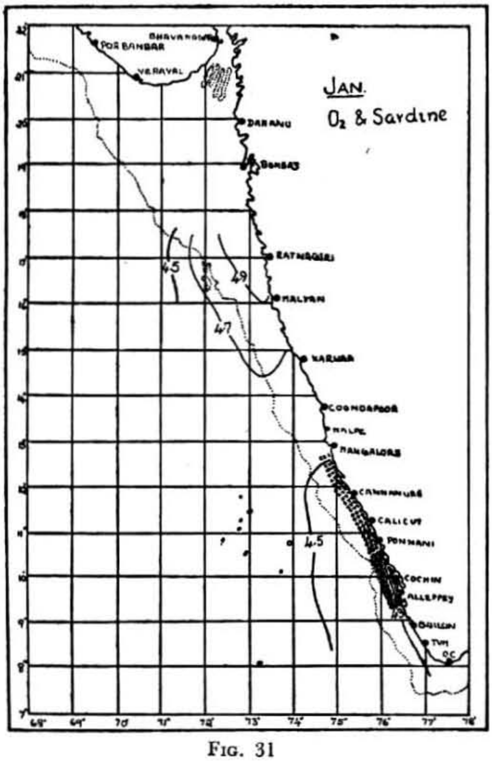

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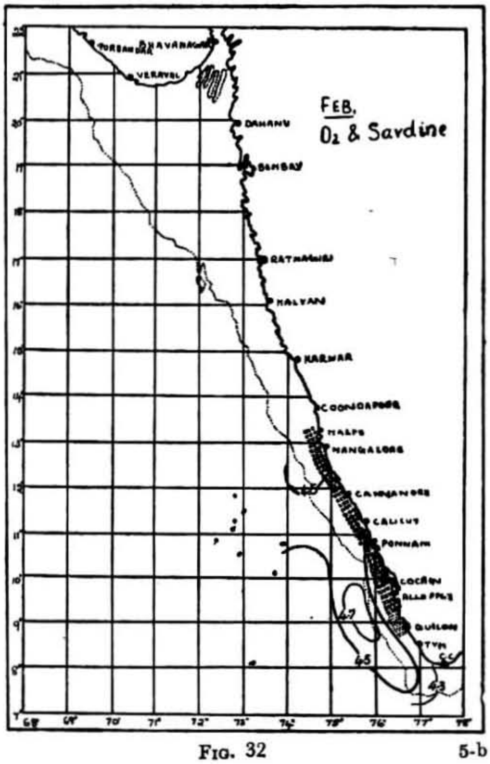

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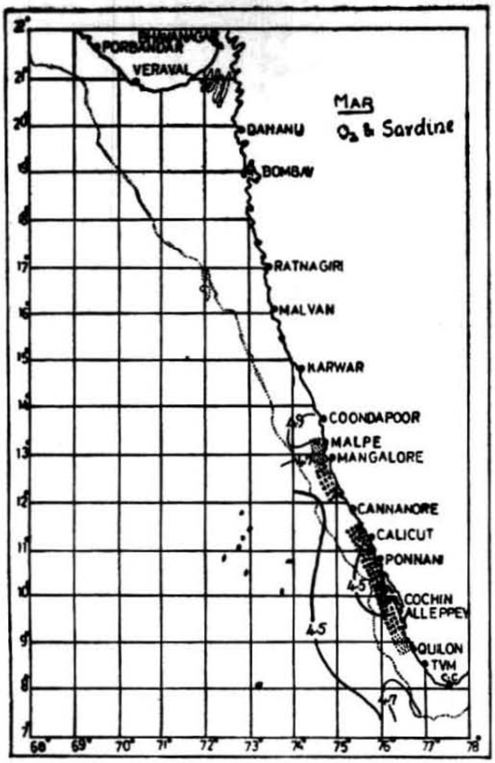


FIG. 33

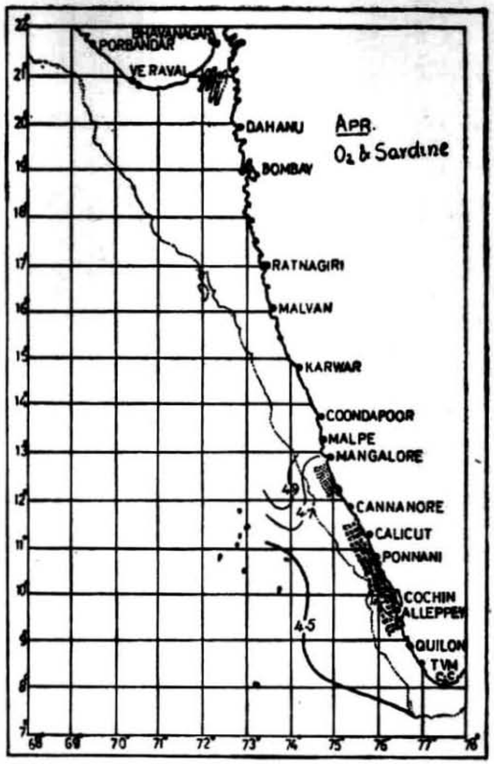
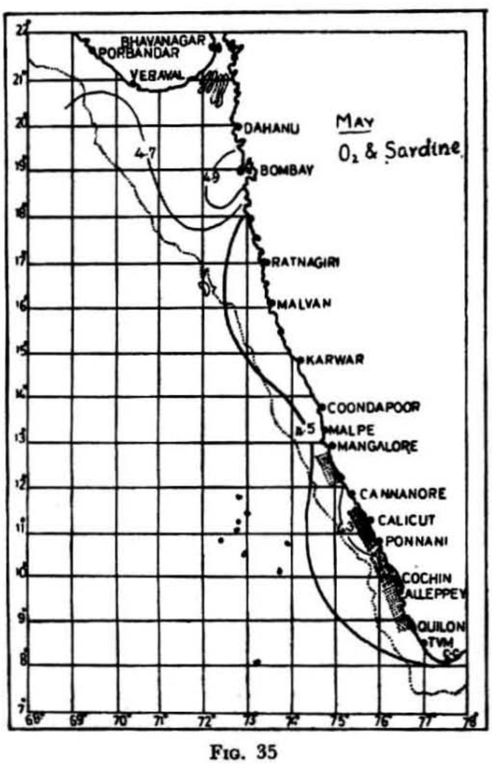


FIG. 34



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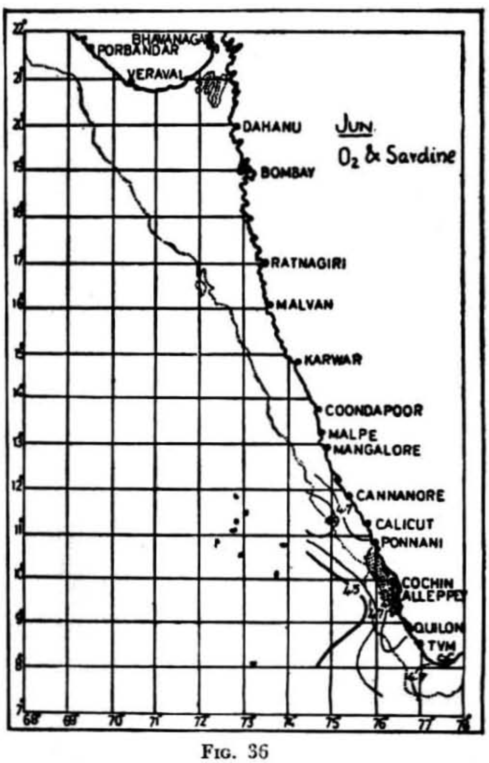
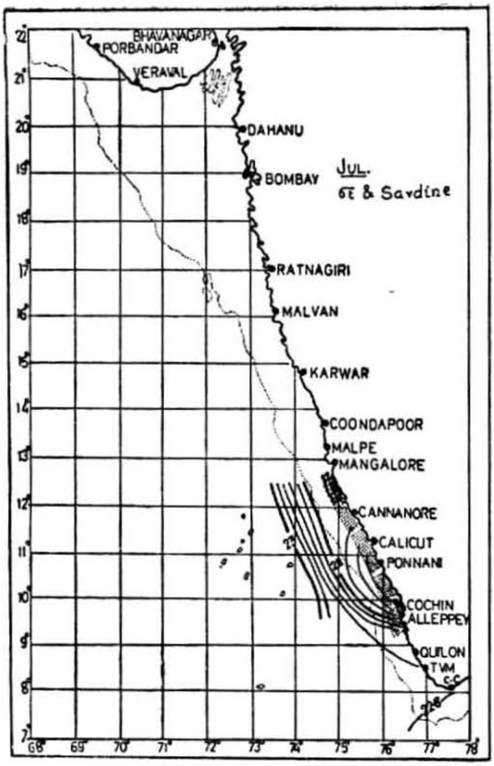


FIG. 36



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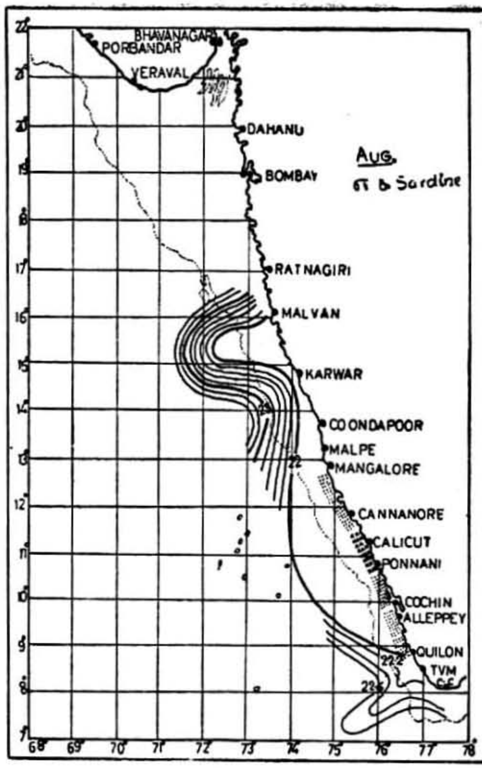

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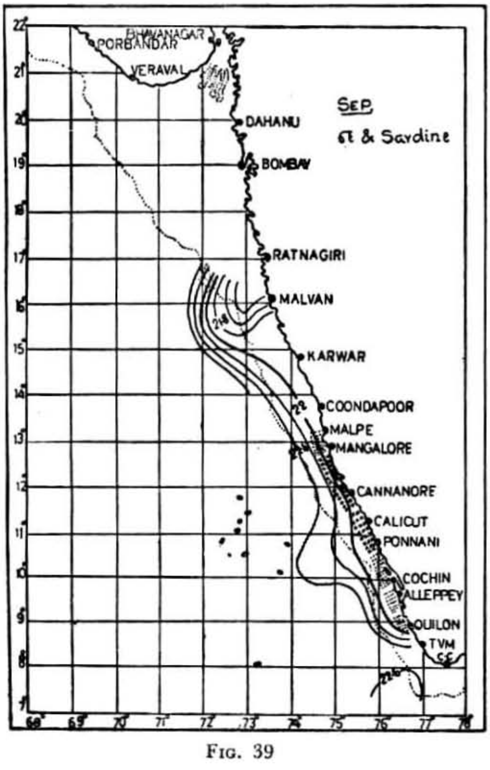


FIG. 39

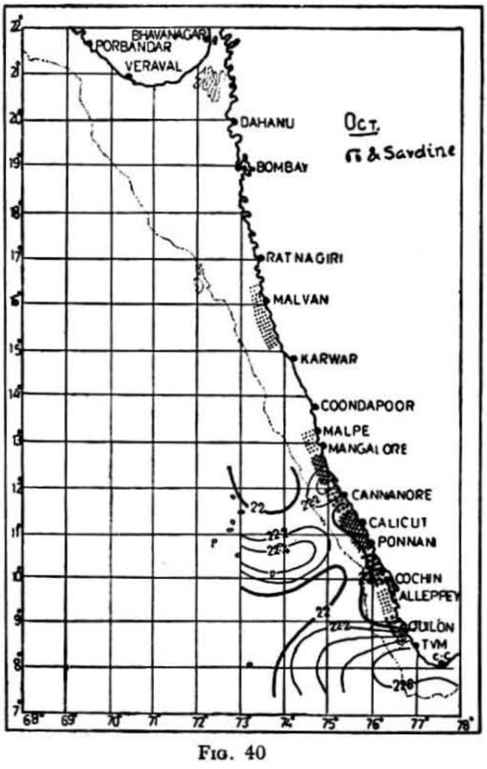


FIG. 40

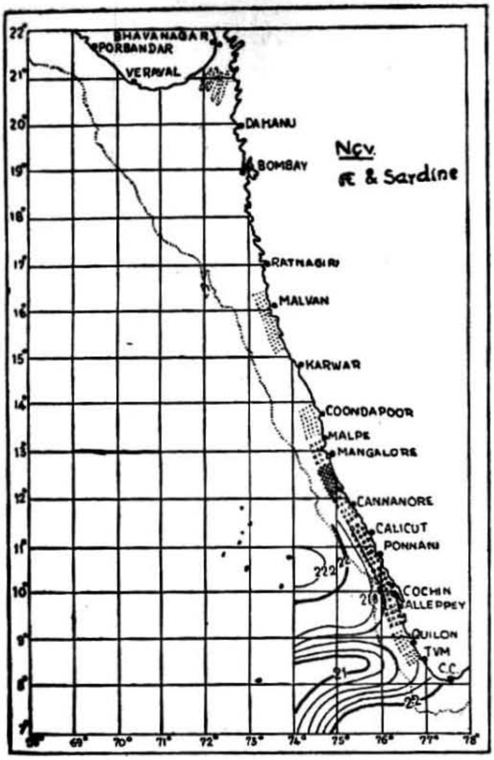


FIG. 41

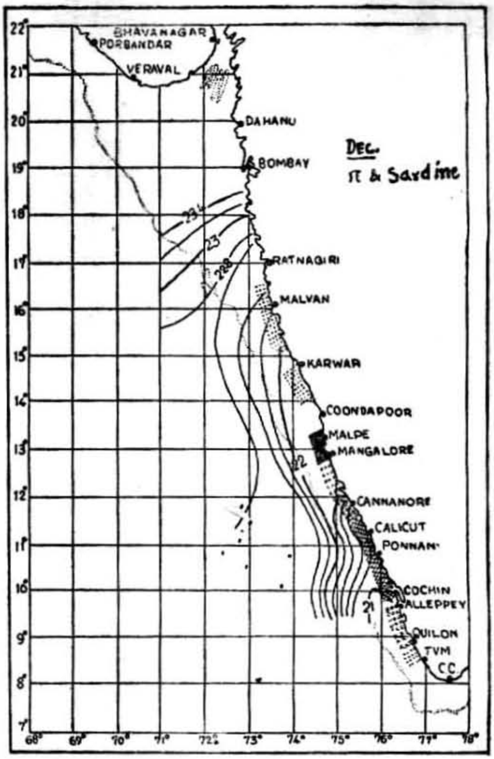


FIG. 42

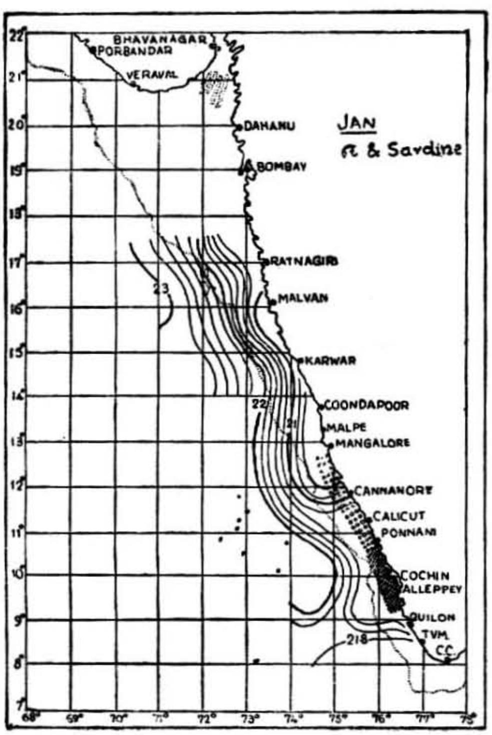


FIG. 43

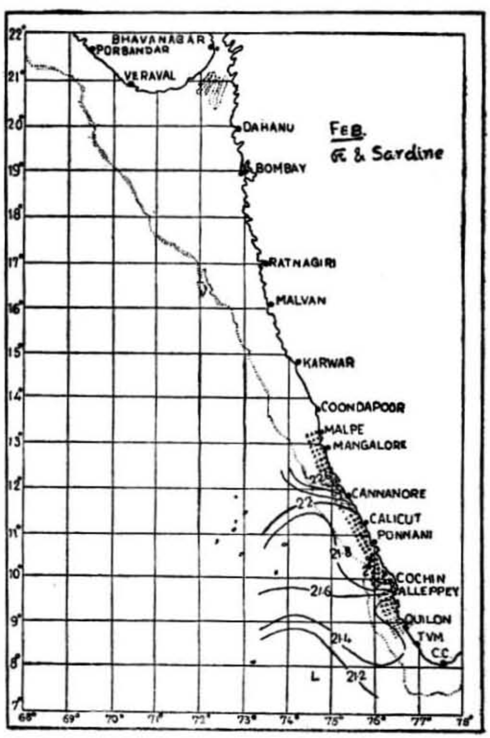
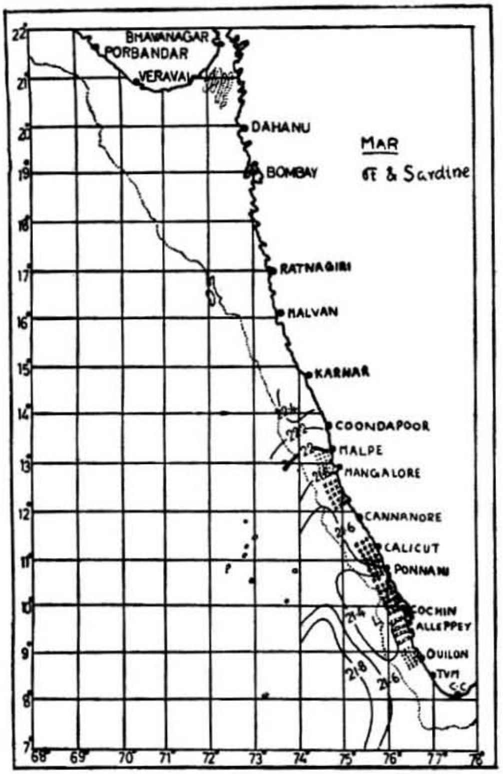


FIG. 44



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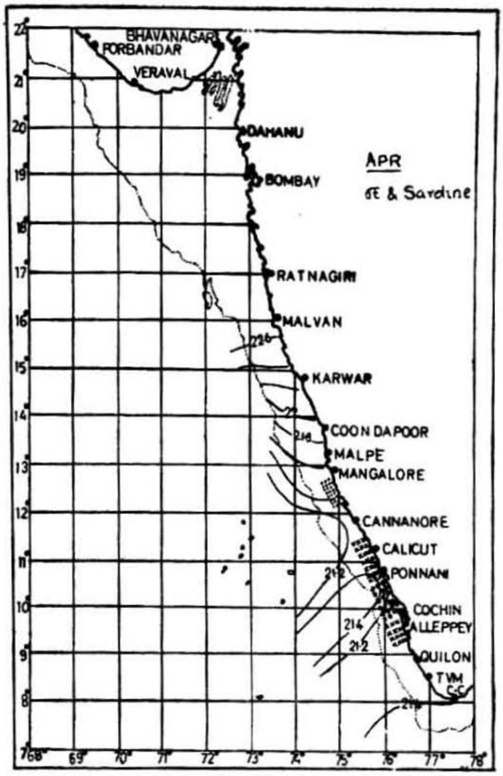
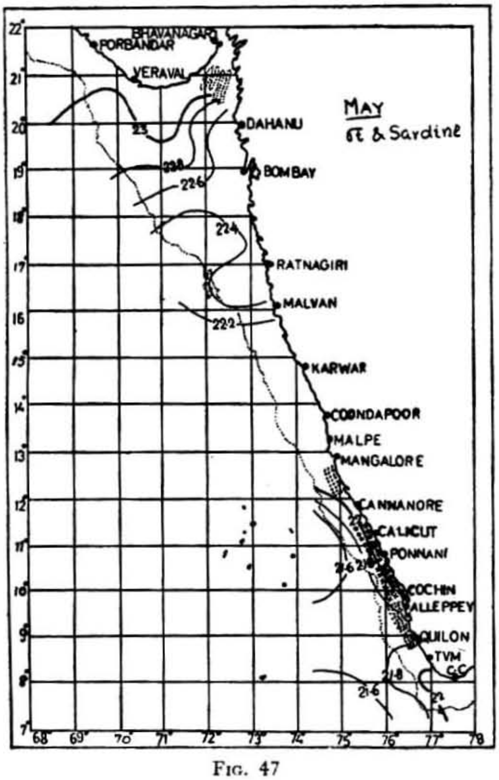


Fig. 46



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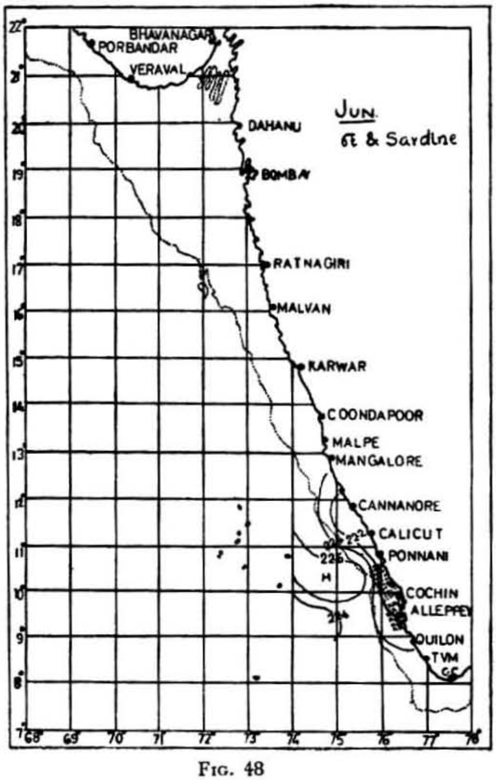


Fig. 48

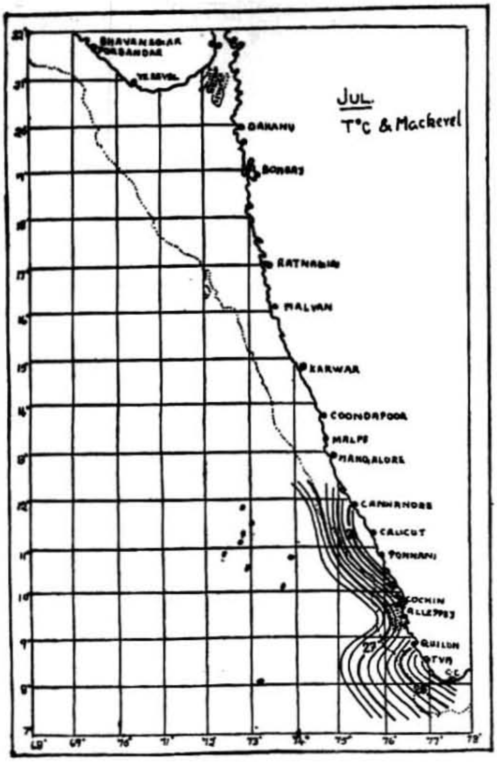


FIG. 49

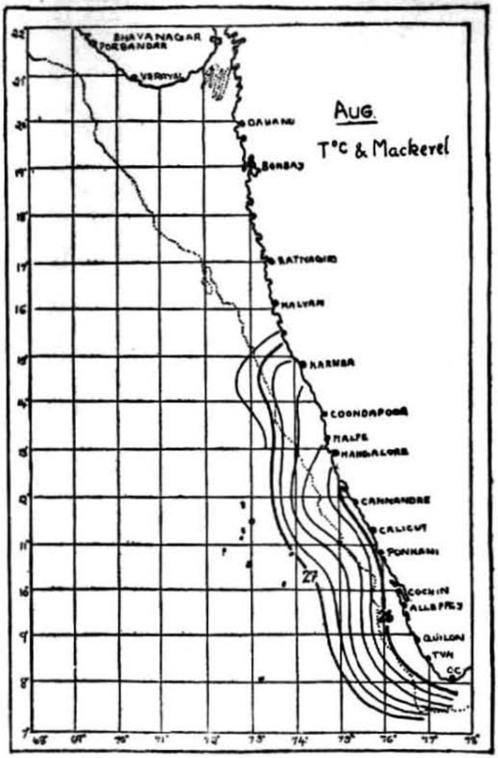


FIG. 50

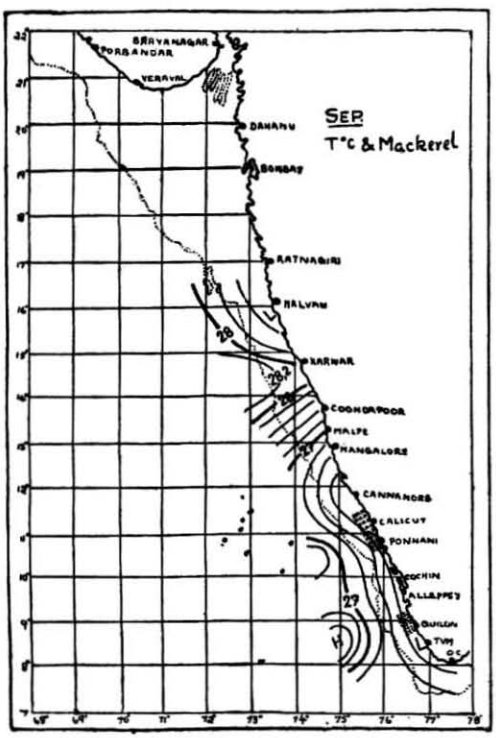


FIG. 51

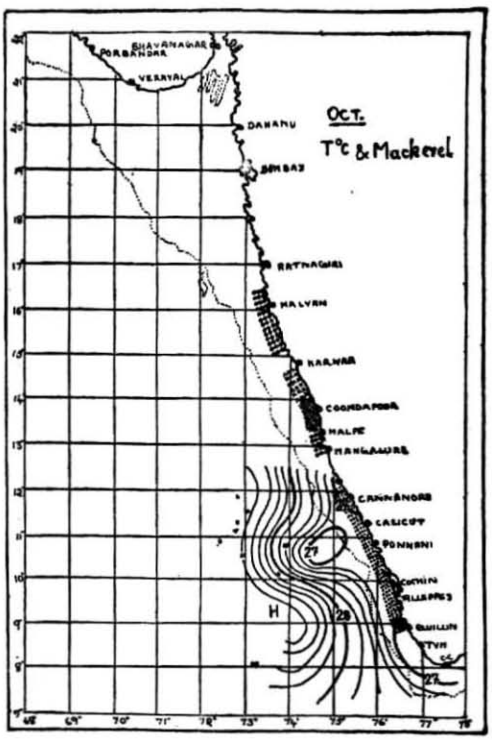


FIG. 52

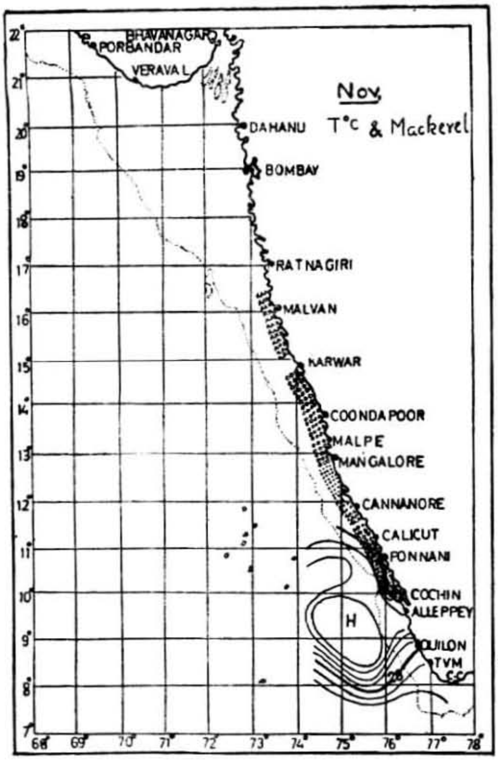


Fig. 53

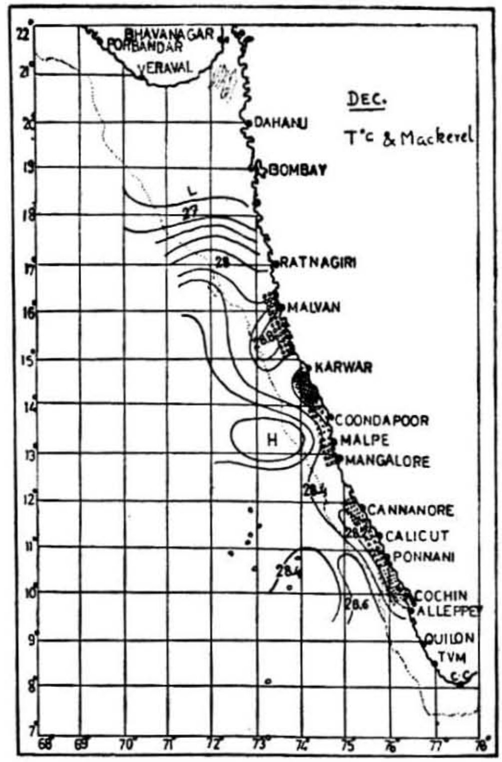


Fig. 54

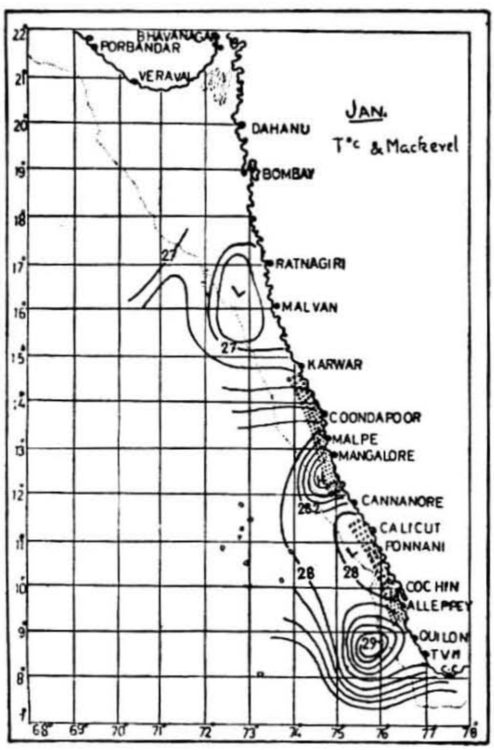


Fig. 55

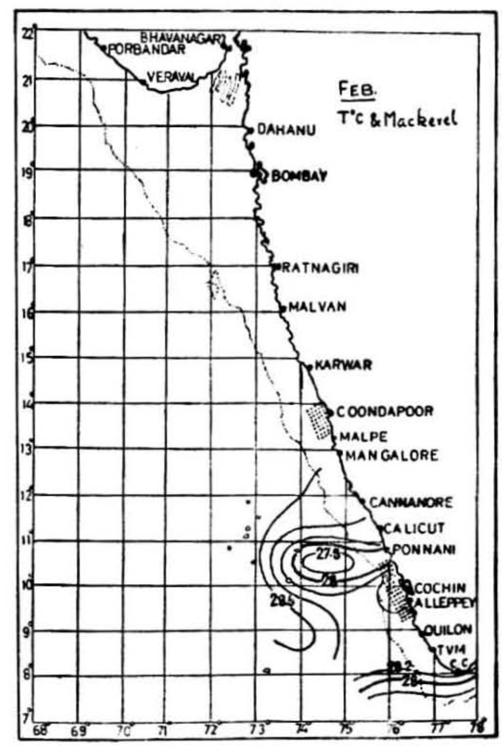


Fig. 56

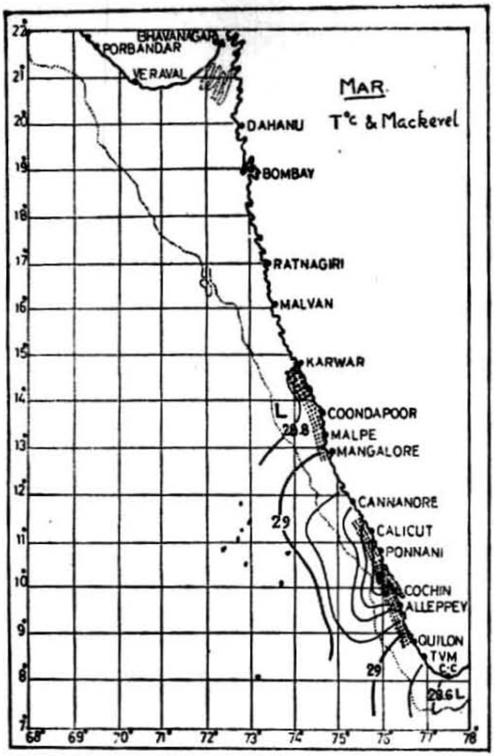


FIG. 57

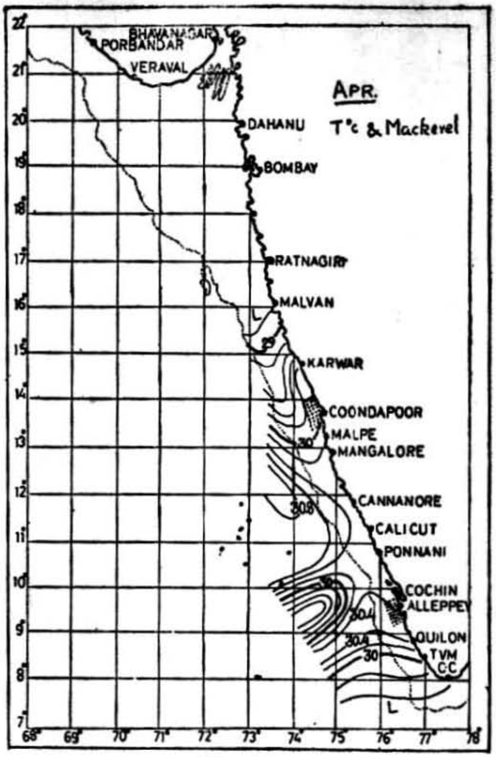


FIG. 58

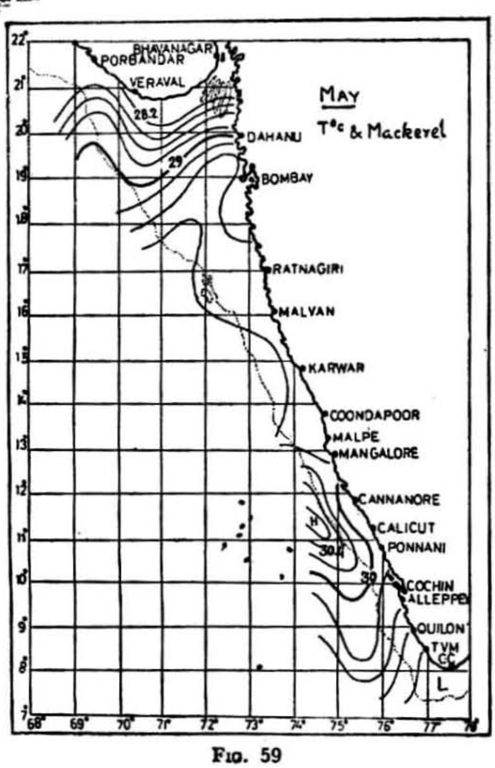


FIG. 59

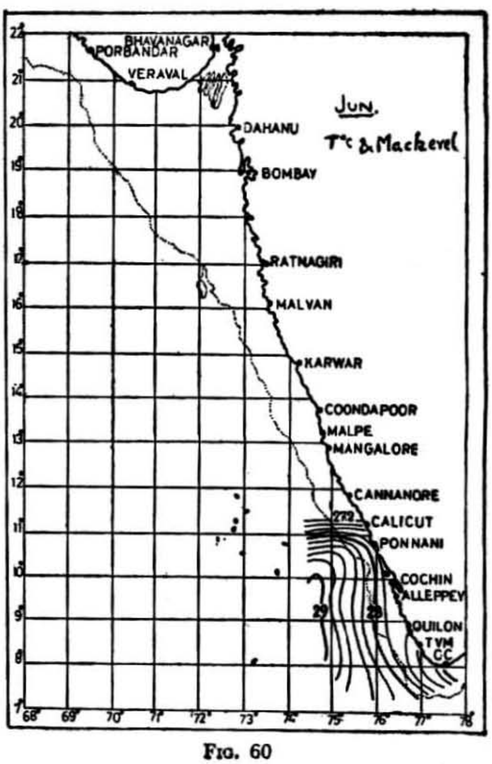
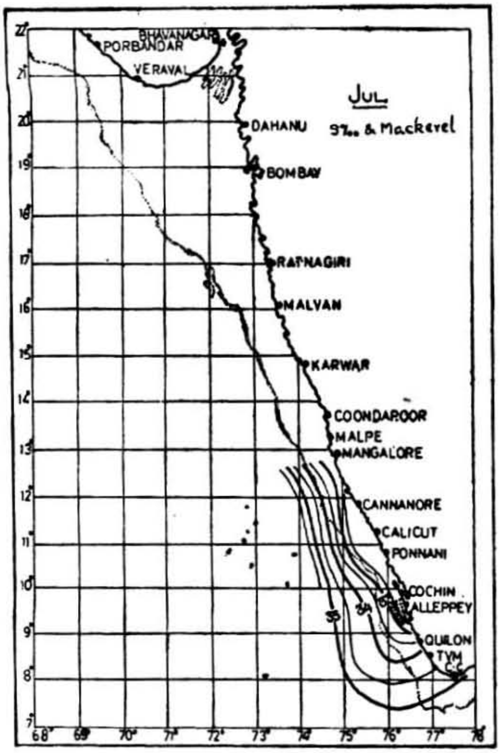


FIG. 60



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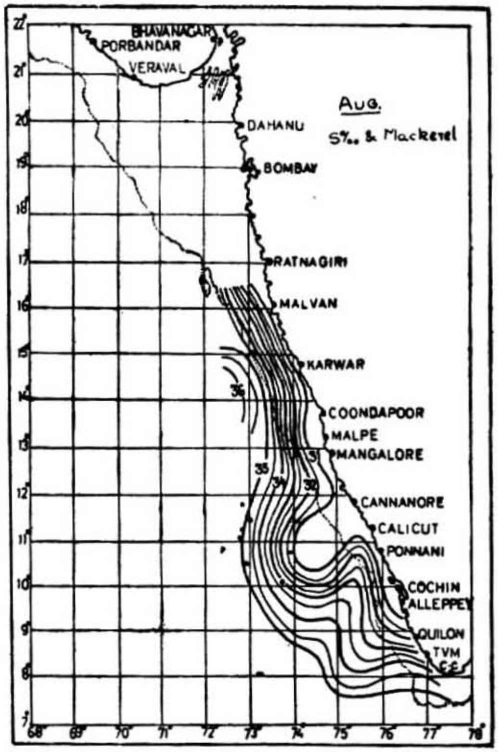

Fig. 62

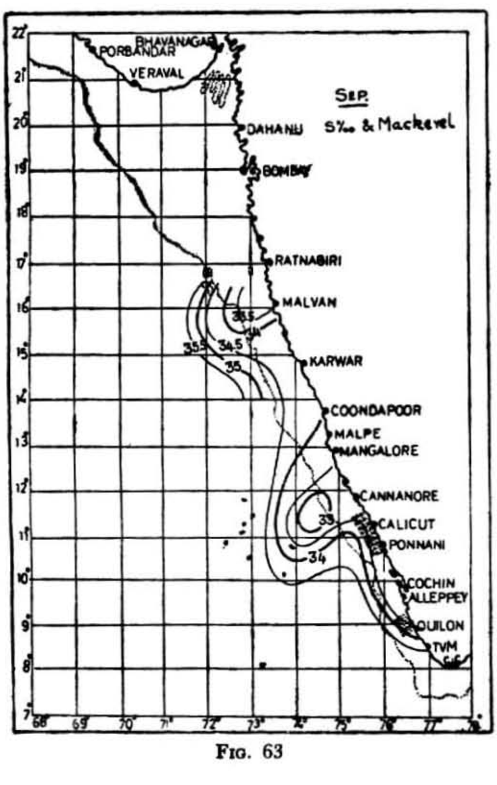

Fig. 63

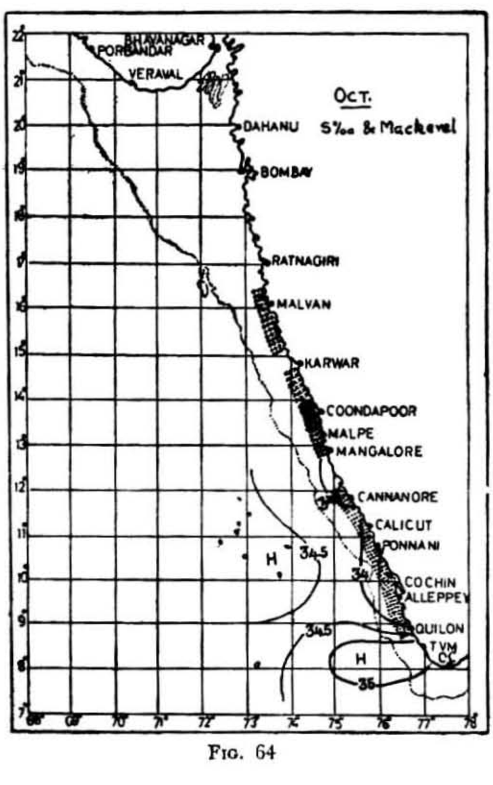

Fig. 64

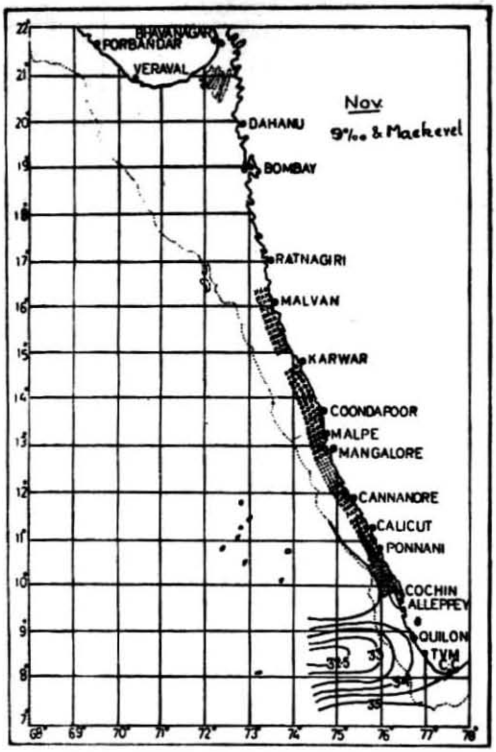

Fig. 65

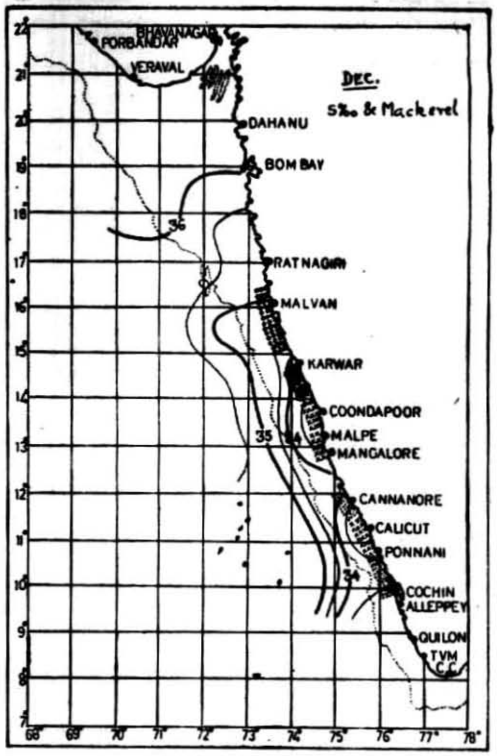

Fig. 66

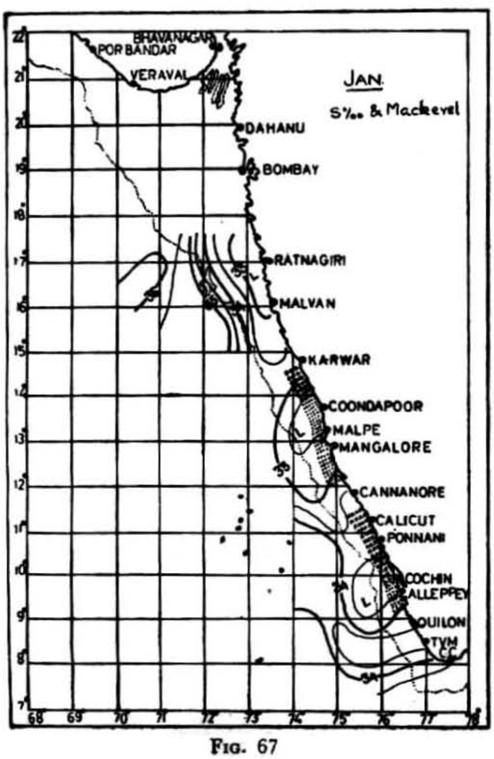

Fig. 67

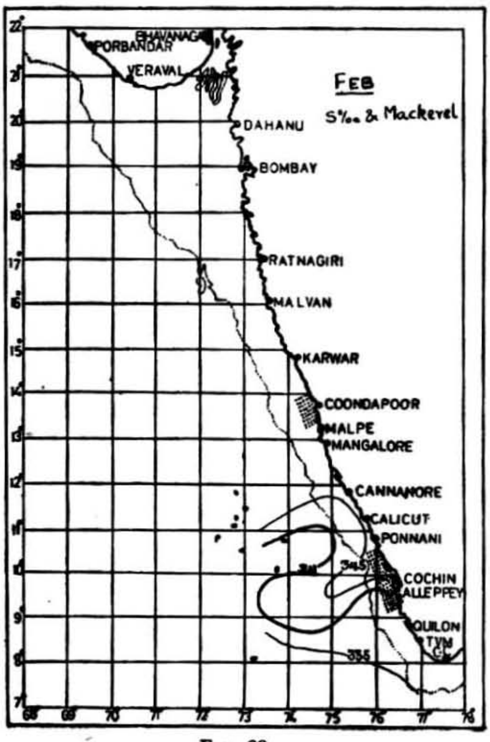

Fig. 68

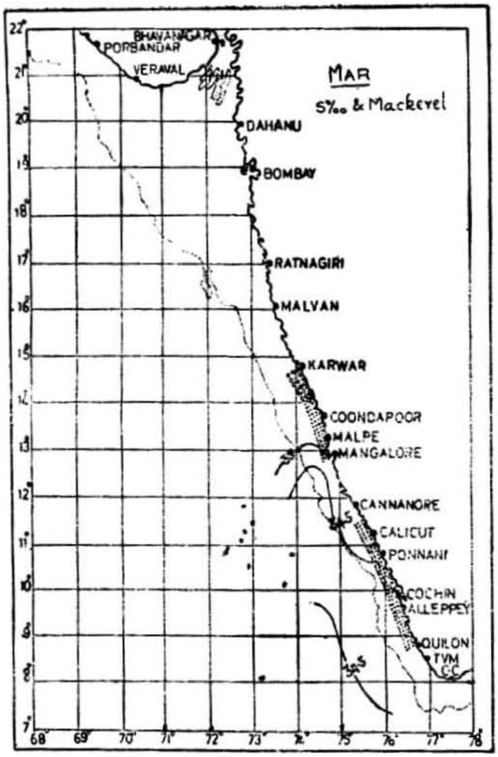

Fig. 69

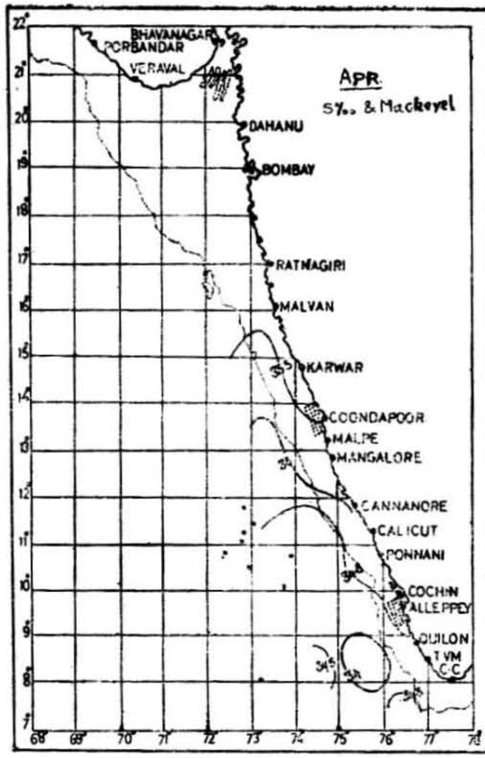

Fig. 70

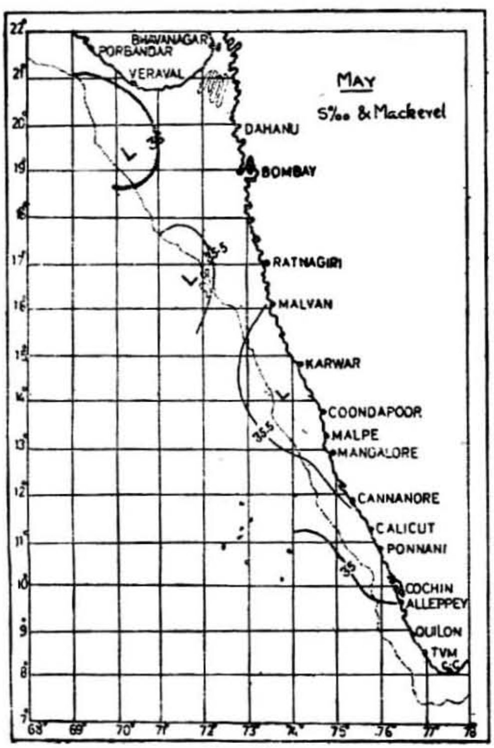

Fig. 71

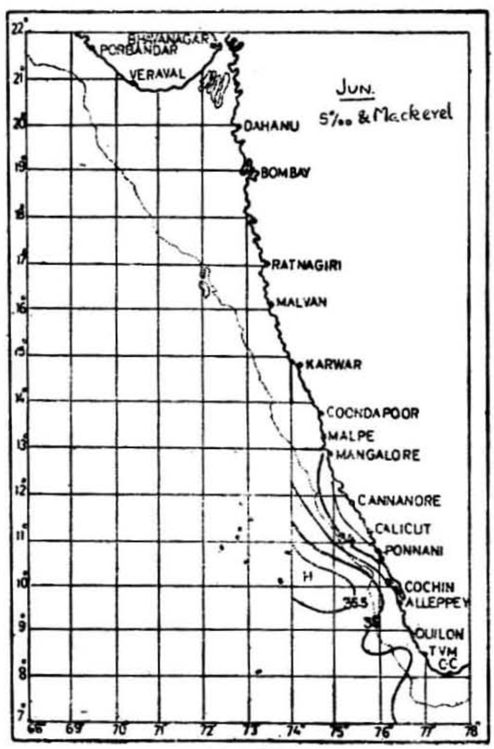

Fig. 72

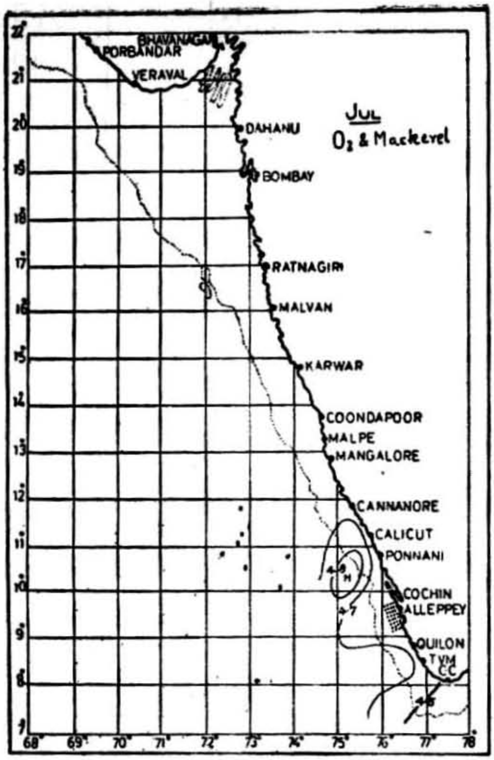

FIG. 73

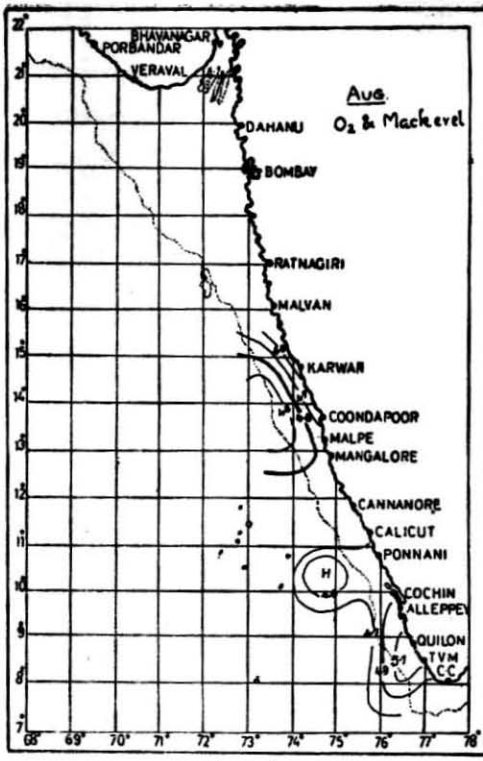

FIG. 74

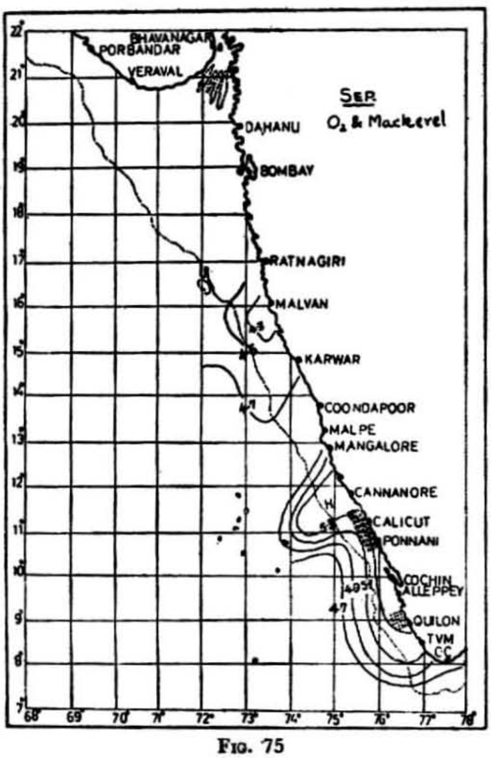

FIG. 75

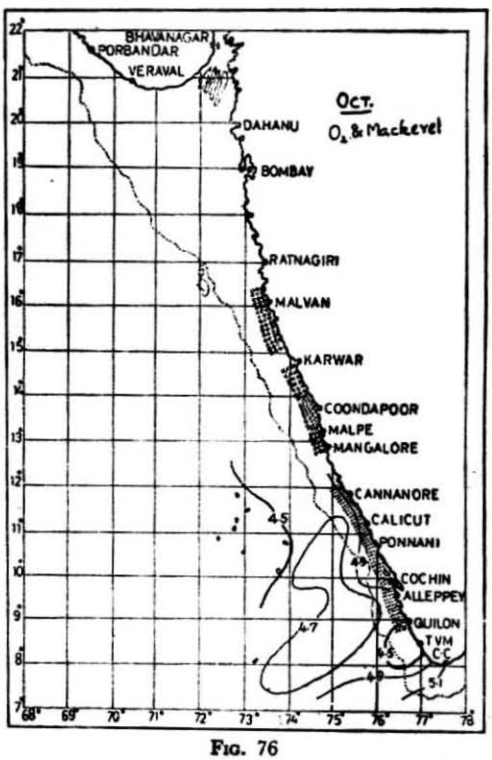

FIG. 76

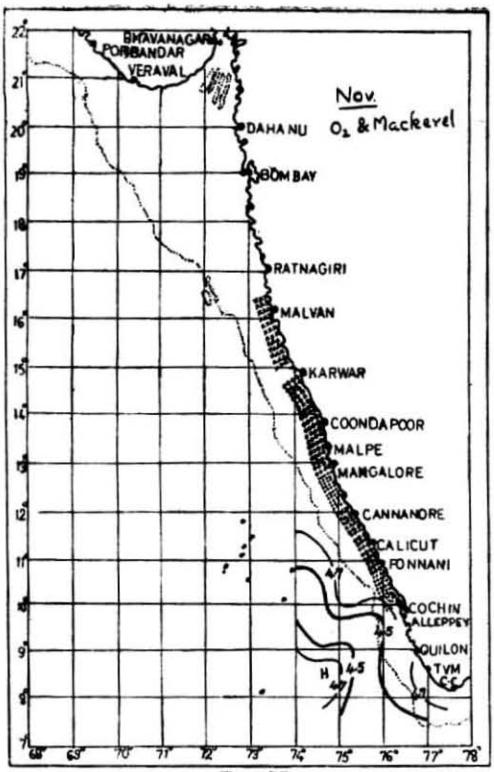

FIG. 77

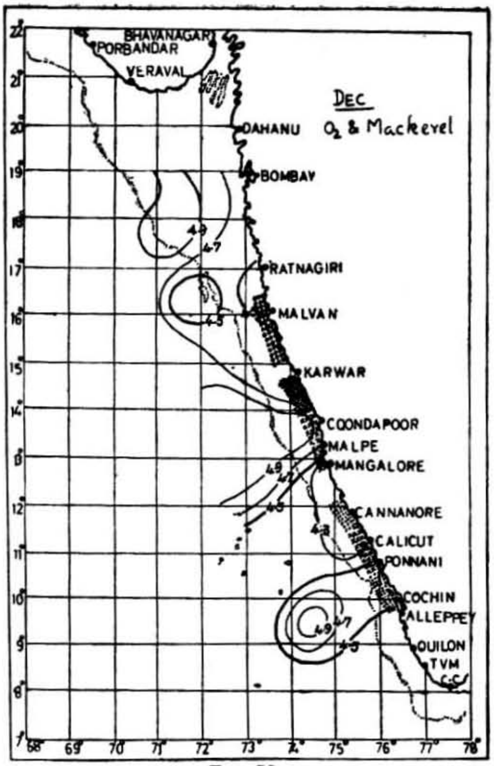

FIG. 78

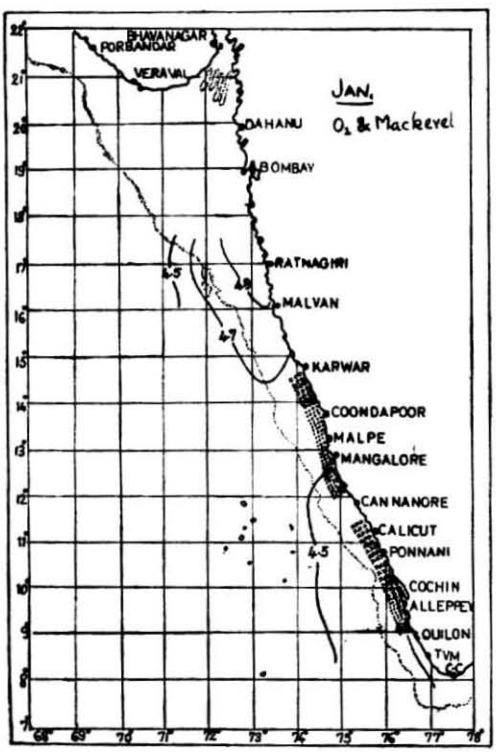

FIG. 79

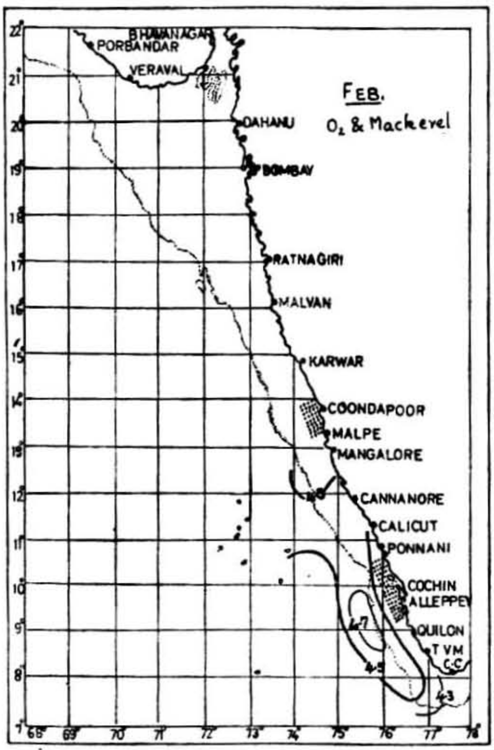

FIG. 80

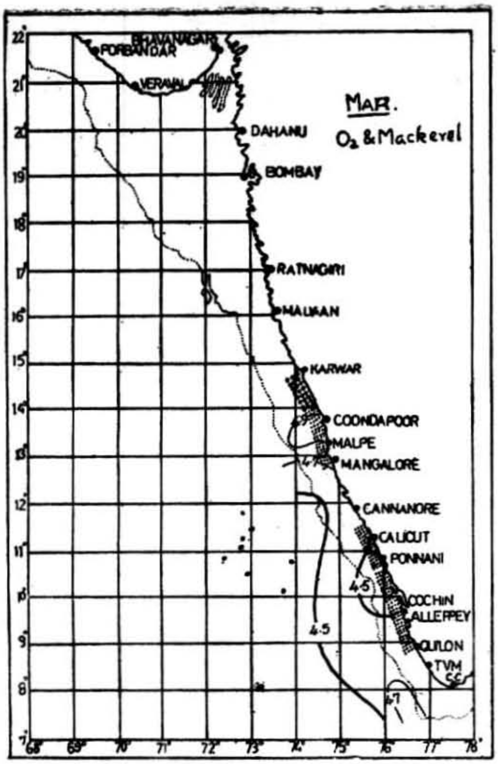

FIG. 81

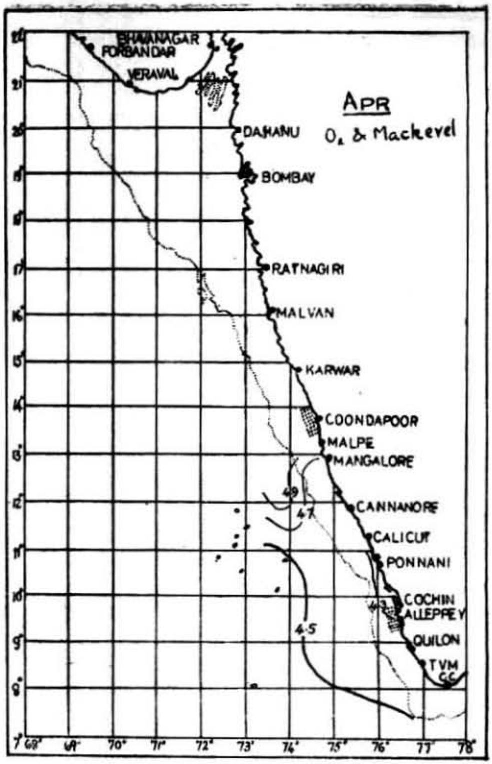

FIG. 82

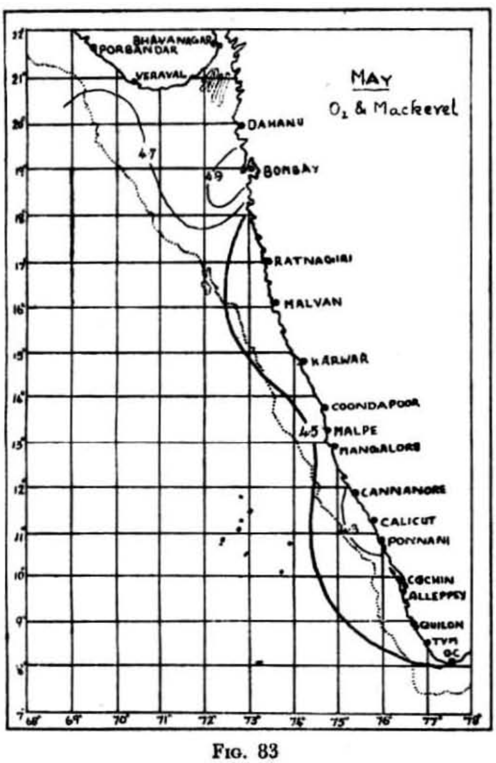

FIG. 83

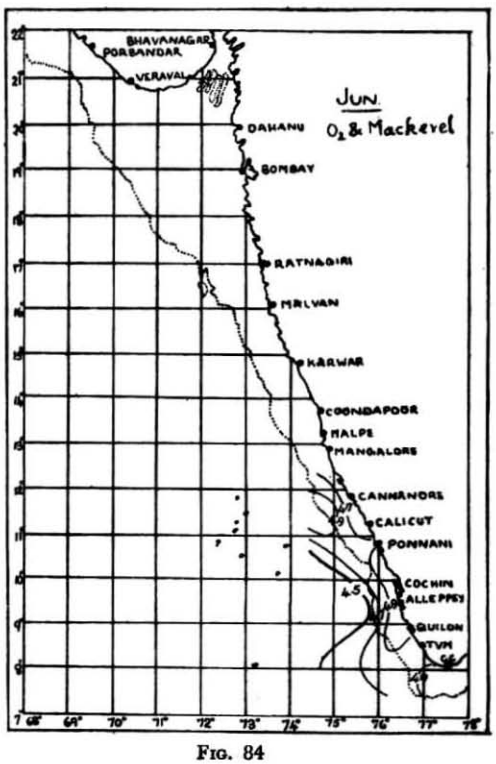

FIG. 84

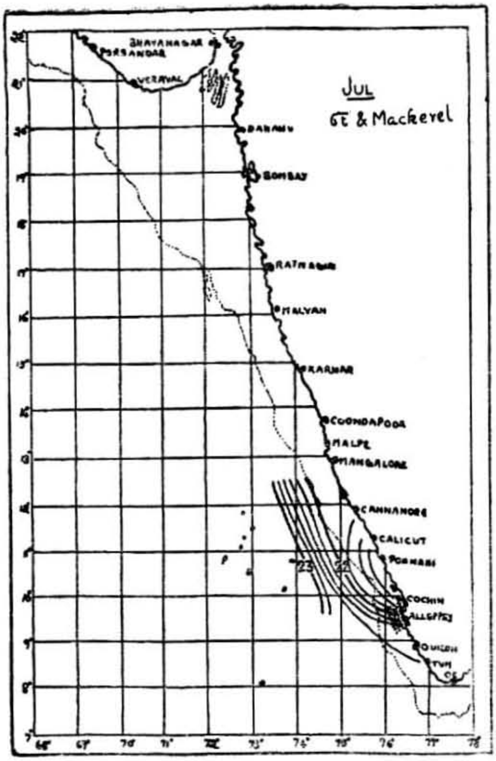

Fig. 85

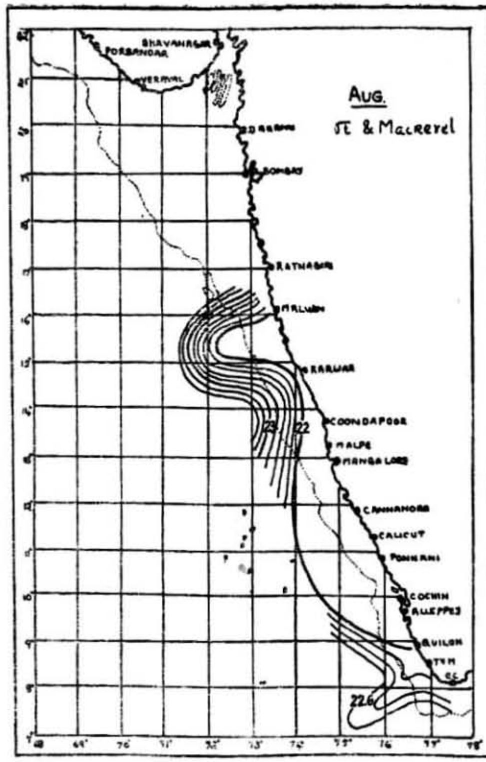

Fig. 86

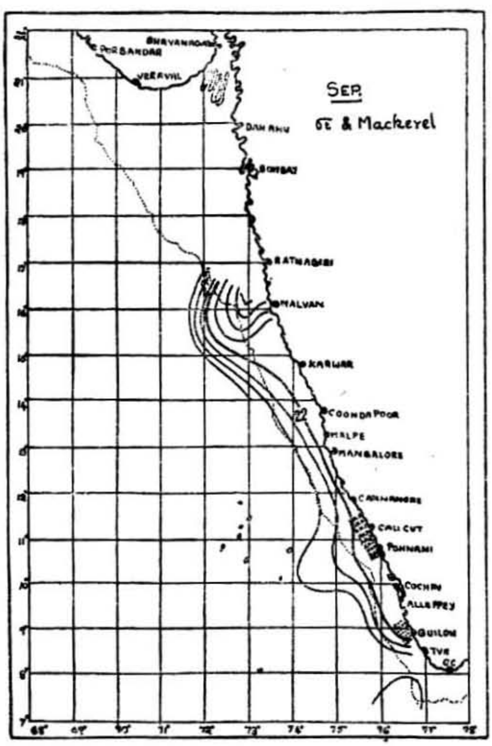

Fig. 87

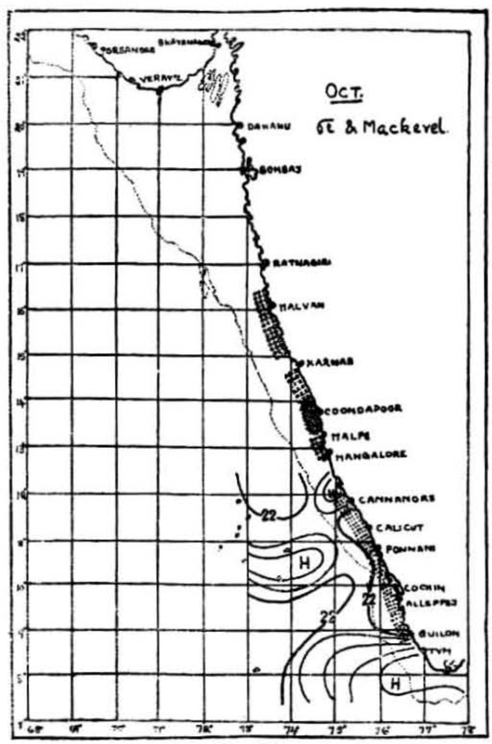

Fig. 88

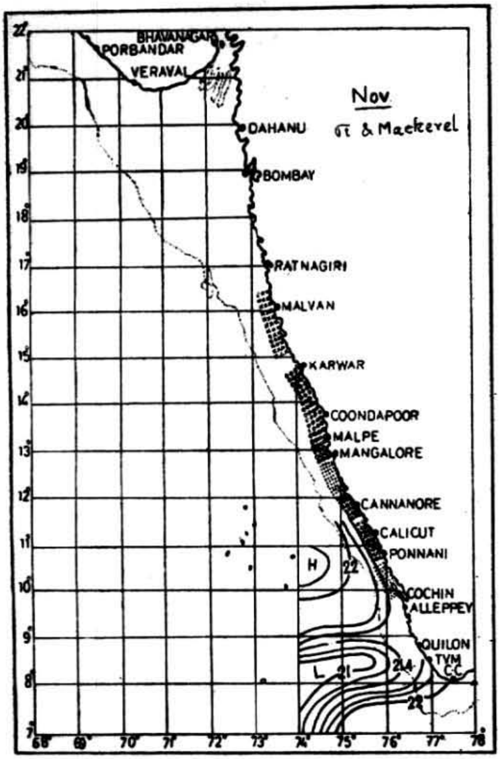

Fig. 89

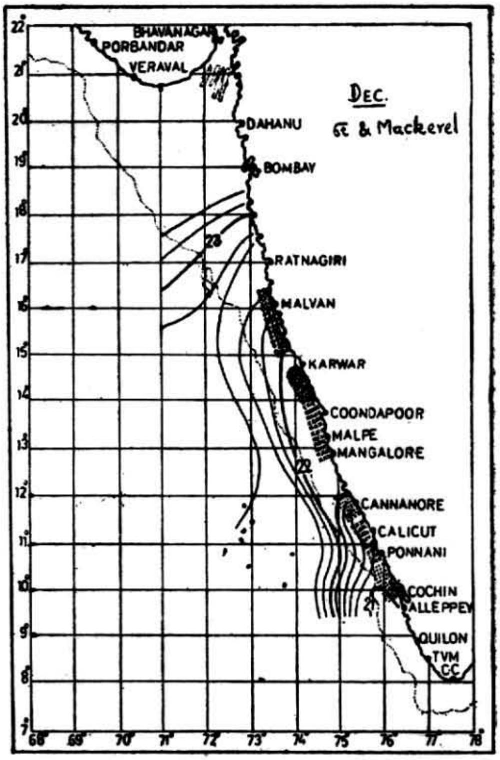

Fig. 90

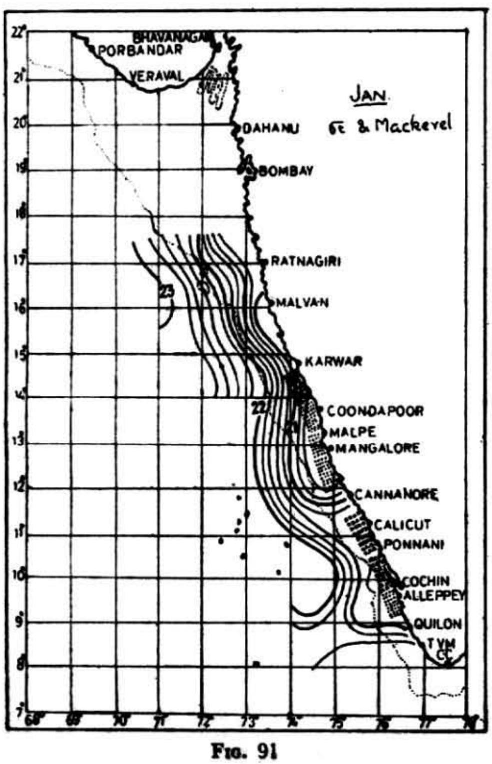

Fig. 91

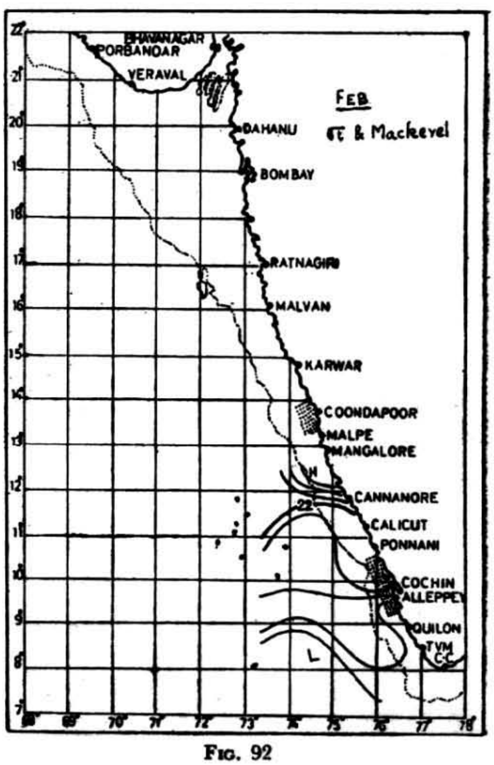

Fig. 92

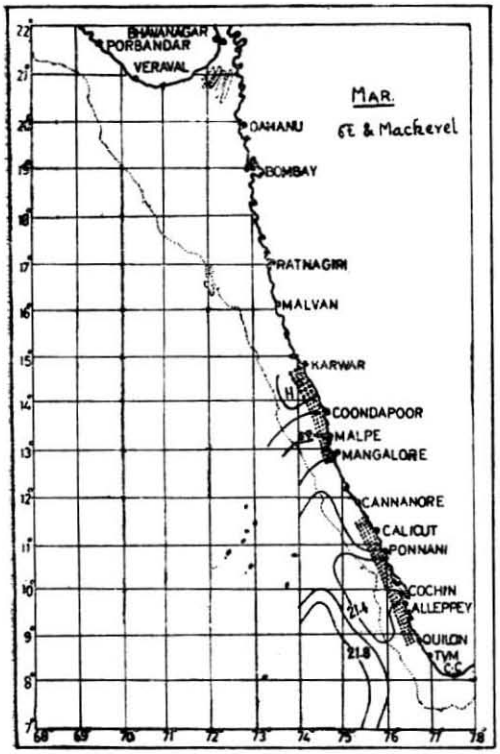

FIG. 93

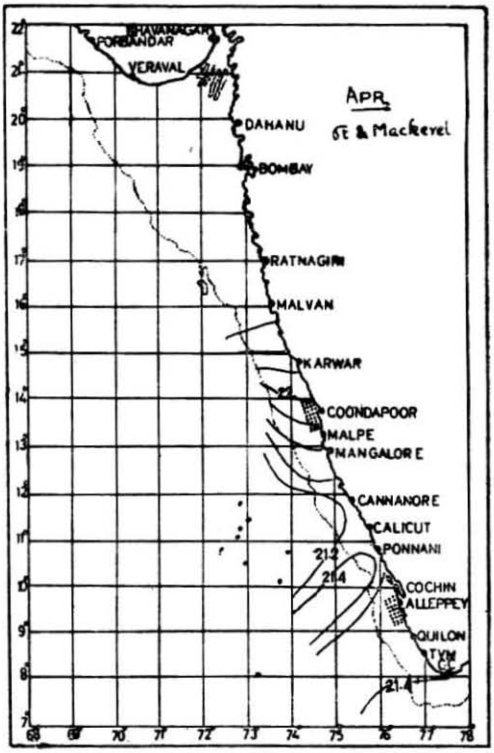

FIG. 94

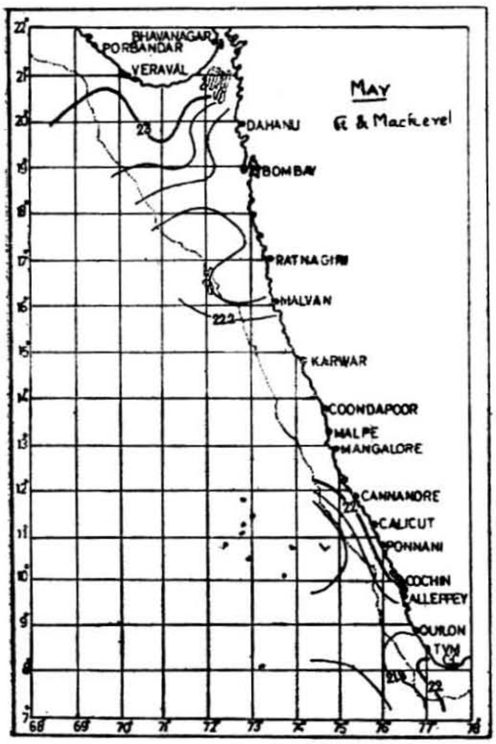

FIG. 95

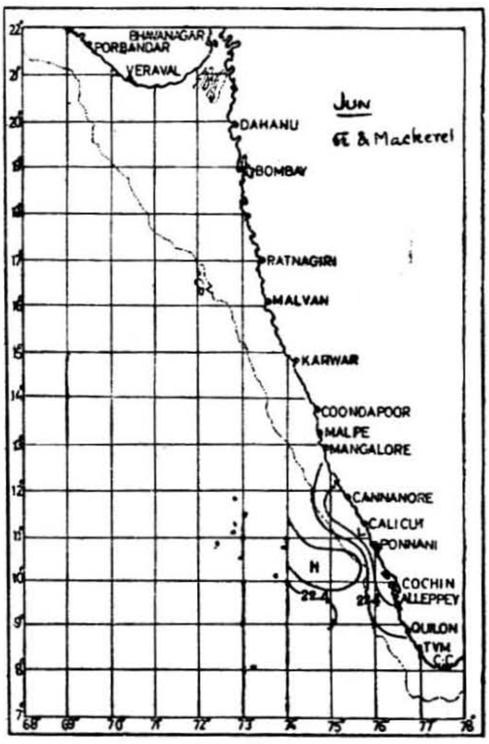

FIG. 96